SR No. 328

MULTIDISCIPLINARY GEOSCIENTIFIC EXPERIMENTS IN CENTRAL EUROPE

Dr. Dieter BANNERT

Bundesanstalt für Bodenforschung
(Federal Geological Survey)

3 Hannover 23
Stilleweg 2, Postfach 23 01 53
Fed. Rep. of Germany

September 1974

Type III Report

Bundesanstalt für Bodenforschung

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14. Supplementary Notes In the main the report consists of the original contributions of the CI-authors. Only the results of geographic investigations have been compiled into a synoptic chapter. Preface, introductory comments on the subdivisions, formulation of conclusions and recommendations was done by the PI. Parts of the results have been presented at the following meetings: Annual Meeting of the Remote Sensing Group of the German Research Council, Clausthal, February 1973
Annual Meeting of the "Deutsche Geologische Gesellschaft", Frankfurt, October 73
Third ERTS Symposium, Washington D. C., December 1973

15. Abstract
Studies for the project were carried out in the fields of geology-pedology, coastal dynamics, geodesy-cartography, geography and data processing. In geology-pedology a comparison of ERTS-image studies with extensive ground data (large scale maps and geological surveys) led to a better understanding of the relationship between vegetation, soil, bedrock and other geologic features. New findings in linear tectonics gave better insight in orogeny and the development of ore deposits, being used in practical ore prospecting. The coastal studies proved the value of ERTS-images for the updating of nautical charts. Geodesists and cartographers showed possibilites and limitations of using ERTS-imagery for the preparation of small scale topographic maps. To the geographers it seems rather difficult to find ways of application of ERTS-studies for actual problems. With better repetative coverage and the use of more sophisticated data processing, however, future application in the monitoring and planning of urban development appears promising. Data processing in general made a big step forward towards automated image analysis and image processing. A plotter for large scale high speed image generation from CCT was developed.

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1. PREFACE:

The objectives of the investigation into ERTS-1 imagery taken over Central Europe were to prove the possible application of space data for geoscientific evaluation. Furthermore it seemed to be desirable to evaluate future useful application of space observations of this particular region of the world. In addition to these objectives the study of ERTS-1 imagery prompted a number of relevant decisions as to whether or not to develop a German or European earth observation satellite, or to build an ERTS receiving station. [redacted]. Data processing and remote sensing will be promoted more than in previous years and a large part of Governmental supported geological projects outside Germany uses ERTS 1 imagery over the specific sites as a routine investigation.

The main objectives of the investigations so far carried out relate to the following disciplines:
Geology-Pedology, Coastal studies, Geodesy-Cartography, Geography, Data processing.

The ERTS-1 images were evaluated by different Co-I. under different disciplines. Their final results are reprinted under the respective author's name and title in this final report.

The main findings as described in the articles are:

Geology:
Mainly structural elements partly unknown so far have been detected in various regions of Central Europe. Their practical and scientific value is not yet fully understood. However, some larger lineations seem to be quite remarkable.

R. MÜHLFELD (chapter 2.1.1) found a long lineation which signalized an underground tectonical fracture which could only be discovered by seismic surveys, the surface expression of which was not known due to its overburden of several hundred meters of mostly unconsolidated younger bedrocks. ERTS-1 imagery shows the influence of this fracture over more than 100 kms.

P. KRONBERG (chapter 2.1.3) prepared a lineation map of major parts of Germany and compared it with a modern map of the same scale (1 : 1 000 000). He could demonstrate that the intensity and the azimuths of the lineation pattern differ considerably from the dominating fracture pattern known so far.

Like MÜHLFELD (2.1.1) he could demonstrate that the lowlands with only a few fractures and fracture zones known so far revealed most of the new lineations.

J. BODECHTEL and B. LAMMERER (chapter 2.1.4) evaluated the Alps and their forelands and found lineations which are partly known from previous ground surveys but which never have been brought into relation to each other. As their figures demonstrate, the Alps are crossed by these lineations throughout their whole extent.

They were also able to differentiate between tectonical lineations and ice flow lineations. So the connection of the foreland ice age morains with their glaciers can now be demonstrated.

To a certain degree it is possible to identify different rock types and soil types on ERTS-1 imagery taken over Central Europe. It must be considered that almost all features visible relate to man made features. Hundreds of decades of agriculture and forestry changed the natural cover of the landscape. However, certain types of agriculture are still related to specific soil conditions. Coniferous trees in contrast to deciduous trees very often signalize bedrocks and soil types rich in SiO_2. But due to the high standard

of geologic knowledge no new information on lithologic units could be derived.

As MÜHLFELD (2.1.1) could demonstrate, seasonal changes in vegetation are also important for the delineation of lithological units. Especially late summer conditions seem to be most favourable for this type of analysis.

The major pedological units, which occur in larger areas with minor morphological differences can be clearly delineated (MÜHLFELD, chapter 2.1.2, BODECHTEL and LAMMERER, chapter 2.1.4). However, the pedological mapping in Central Europe has been brought to a scale of 1 : 25 000 and larger. ERTS-1 imagery is now used in an experimental stage for small scale field mapping (1 : 200.000).

Studies of coastal processes - as all fast dynamic processes - seem to benefit more from ERTS analysis. P. HOPPE (chapter 2.2.1) could demonstrate by comparison of sea-bottom features analysed on ERTS-1 imagery near the German coast with most recent nautical charts, that even close to the international nautical routes major changes occurred in the tidal flats. One to two coverages per year under high tide conditions seem to be sufficient to control the navigation charts and detect major changes which require ground control.

H. KNORR and R. FÖRSTNER (chapter 2.3.1) prepared photomaps of selected ERTS-1 scenes (band 7). Both 9 x 9 inch bulk transparencies and 70 mm bulk transparencies had a sufficient geometric accuracy which is within the drawing accuracy in the respective scales. Combinations of band 5 and band 7 can be used to update small scale topographical maps. CCT playbacks of the scenes in the scale of 1 : 200 000 revealed too much detail for topographical maps of this scale. Forest areas can be identified in sufficient detail to produce a map in the scale 1 : 100 000 (DANIEL, report cited).

Geographical studies showed, that major land forms and land use units can be clearly delineated. The close correlation between land forms and geological underground is obvious. A major application was found in the monitoring and planning of urban development particularly in heavily industrialized areas such as the Saar-Nahe-Region, Ruhr-Region, or the Rhein-Main-Area.

During preparation of ERTS-A proposal in 1971 data processing was in an experimental stage. In the meantime facilities in Hannover and Munich are established to process imagery and to work on automated data processing and image analysis from CCT. [redacted]

Conclusions

The evaluation of ERTS-1 imagery of Central Europe has confirmed to a large extent it's anticipated value for geoscientific studies. Especially for linear tectonics the wealth of new data was surprisingly high. It is obvious, that so far only in limited areas this value of ERTS-imagery could be proved by detailed field check and literature survey. However, ERTS-1 image evaluation is now included in a major mineral survey project in the palaeozoic rocks of the Rhenish Massiv. On an experimental basis ERTS-1 imagery is used during geological field mapping in the scale of 1 : 200 000 in the North German Lowlands. Scientific geological studies on regional tectonics are initiated by ERTS-1 image analysis in several parts of Central Europe.

Data processing made a big step forward towards automated image analysis and image processing. High resolution image production from CCT is available now on a commercial basis by Prakla-Seismos G.m.b.H., 3 Hannover, Haarstraße 5, and can be used under operational conditions.

For the future it seems to be recommendable to apply ERTS-data to the study and observation of large and medium scale dynamic processes as for example:

- annual changes in the distribution of tidal flats and channels which will lead towards a faster and more precise production of nautical charts,
- the studies of smog concentrations over urban and industrial areas which will necessarily require additional aircraft underflights, regional planning in urban areas including the fast updating of small scale thematic maps.

During the period of studies of ERTS-1 imagery it became obvious that basic research in the fields of applied remote sensing techniques has to be increased and stimulated by a central organisation. Within this scope preparations are now being conducted which, it is hoped, will lead to a national program of remote sensing.

2. Results

The results of the multidisciplinary geoscientific investigation of Central Europe are described below. Although several desciplines have been involved over a period of 2 years, the new findings are not as striking as in many other regions of the world. A very high standard of knowledge - resulting in many thousands of scientific publications - and a comparably very small group of investigators is one reason. Also the lack of organisations fully devoted to remote sensing hampered the investigations. The application of space imagery was only familiar to a few scientists when the first ERTS-1 images arrived in Germany. However, the wide distribution of the images started a new development. In particular universities but also private companies make more use of the images as a tool for special investigations. So it is expected, that in the future additional significant results will be achieved by the use of space imagery for detailed investigations.

2.1 Geology - Pedology

Geological investigations of ERTS-1 imagery was one of the major purposes of the whole program. So the conditions are quite favourable to evaluate the potential benefit of ERTS-studies for geological investigations. The geology of almost every part of the country has been mapped in the scale of 1 : 25 000. But the standard of the maps varies considerably. However, there are reconnaissance maps in the scales between 1 :1000 000 and 1 : 200 000 available, which incorporate the contents of the large scale special maps. Therefore, most ERTS-investigators use the modern reconnaissance maps as standard references when they compare their results with the present knowledge.

Only for special investigation do they go more into detail and use all the information which is published in literature and maps to their full extent.

As the following contributions show, new information on Geology and Pedology could be derived from the ERTS-imagery.

Most of this information relates to linear structures, which are visible through dense vegetation. The vegetation patterns are completely influenced by man, so that those lineations which are still visible have to be really dominant features.

2.1.1. Relationship between vegetation, soil, bedrock, and other geologic features in moderate humid climate (Central Europe) as seen on ERTS-1 imagery by Richard MÜHLFELD - FEDERAL GEOLOGICAL SURVEY - Hannover

2.1.1.1. Introduction

Except for settlements, roads etc., the land surface of Central Europe is almost completely covered by vegetation. It has also been cultivated by man for about 2 000 years. Therefore the vegetation cover represents the different types of land use and their distribution. For the selection of the best suited type of land use, man payed attention to the conditions given by morphology, soil, and bedrock in the underground.

It is for this reason, that geologic and pedologic evaluation of ERTS-1 imagery has to begin with analysis of type and distribution pattern of the vegetation cover and has to study the dependence of land use on the natural pedologic and geologic conditions in the underground. Central Europe, with large scale geologic and pedologic maps and a dense network of geophysical surveys (seismic, magnetic, gravity, geoelectric) offers good conditions for such a study (Fig. 1).

Apart from natural factors, local human conditions such as historic development, customs, and economic systems have an influence on land use. When transferring experiences gained in Central Europe into other less known areas with similar climate, care must be taken to differentiate between human and natural factors.

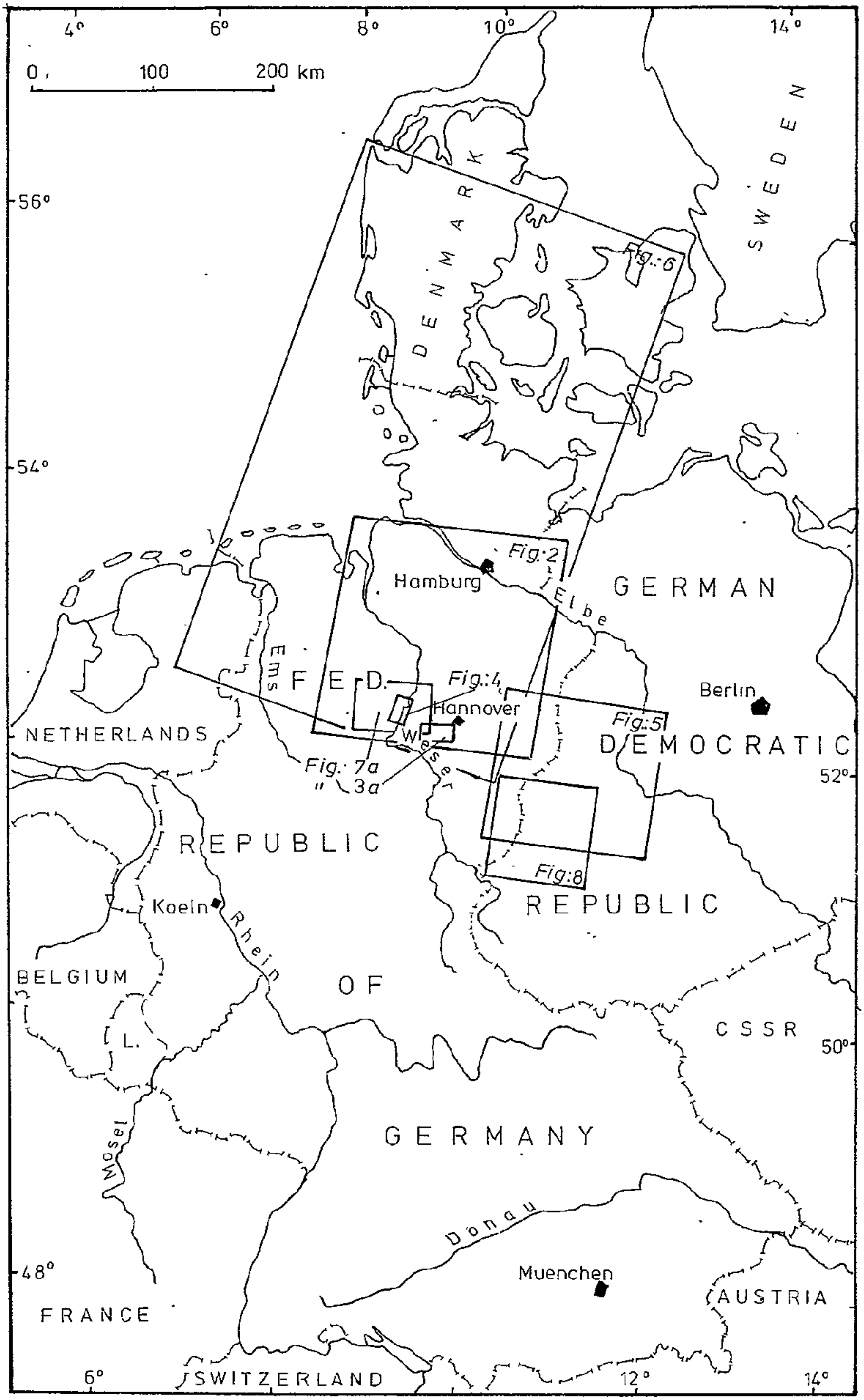
2.1.1.2. Relationship between land use and geological (pedological) units

The following explanations refer to imagery taken during early fall (September) because they proved to show optimum contrast for geological interpretation. (Influence of different seasons will be discussed in section 3.) The image ID is 1060-09534 and covers the major part of Northern Germany (Fig. 2).

Four main types of vegetational land use can be discriminated by comparison of MSS bands 4 - 7:

Pasture land (light tone in band 6 and 7)
Coniferous trees (dark tone in all 4 bands)
Deciduous trees (light in bands 6 and 7, dark in bands 4 and 5)
Agricultural areas are characterized by a typical rectangular pattern (in bands 6 and 7)

In addition some information on bare rock or soil surfaces can be obtained:
Freshly plowed fields (dark in bands 6 and 7, light in bands 4 and 5)
Dry sand (very light in band 5)



Index map of Central Europe

MUEHLFELD, Fig.: 1

2.1.-2a

0 50km

MUEHLFELD Fig. 2

Legend

M Marshlands
S Sandy uplands
P Peatbogs
Glacial drainage network
Photolineations and faults

ERTS-1-Image 1060-09534-7 showing parts of the North German Lowlands with different types of land use, reflecting geological and pedological units

2-1-2B

From the distribution pattern of these land use types it is possible to identify a number of geological and pedological units:

Marshlands, predominantly used as pasture land . They contrast well with adjacent sandy uplands.

Sandy uplands with a high proportion of small size forested areas predominantly coniferous.

Peatbogs, nearly circular features, in the central area with an original cover of small trees and bushes (relatively dark in bands 6 and 7), in the outer part with a circle of cultivated land, used as pasture land.

Sandstone in areas with mountainous relief: Predominantly covered by coniferous forest. The elongated shape of the forested areas indicates the strike direction of the sandstone (Fig. 3 a).

Limestone

In areas with mountainous relief: Predominantly covered by deciduous forest, shape of distribution indicating strike direction as above. In areas of more than about 500 m elevation limestone areas are covered also by coniferous forest. Differentiation between limestone and sandstone is not possible.

In areas with flat relief: Predominantly used as agricultural fields. Due to stage of seasonal work in September bright tone in band 5.

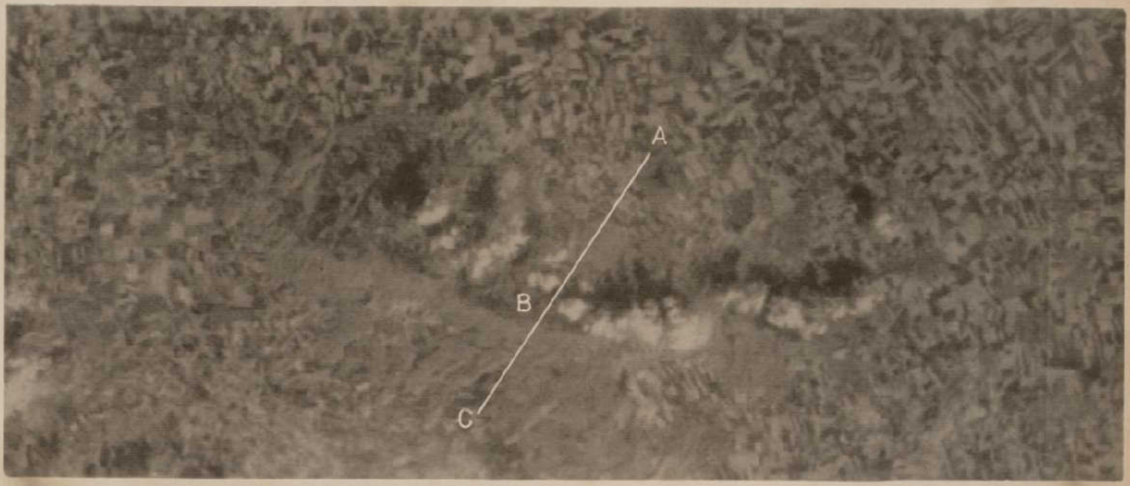
River terraces

As a consequence to the lithological composition of the material of which the terraces consist, their land use contrasts more or less obviously against the environment. An example will be given below in the section on soils.

Different kinds of soils

On the lithological or geological units described above typical soil types are developed:

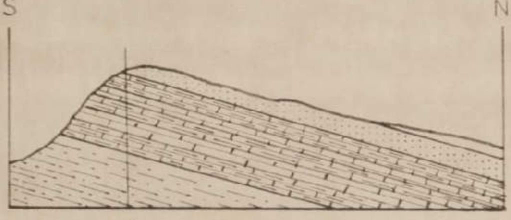
Podzols and gray-brown podzolic soils on sandy uplands (unconsolidated sandy sediments), typical marsh soils on marshlands, brown earths on sandstones, rendzina soils on limestones.



0 5km

ERTS 1060-09534-7 MUEHLFELD Fig.: 3a

Detail of fig.2 showing the Deister hills with different vegetation cover as related to the soil and bedrock composition



	Loess	Quaternary
	Sandstone	Lower Cretaceus
	Marl	Upper Jurassic
	Limestone	Upper Jurassic
	Intercalated marl and limestone	Upper Jurassic
	Siltstone, shale	Middle Jurassic

Fig.: 3b

Geological cross-section through the Deister hills

ORIGINAL PAGE IS OF POOR QUALITY

2.1-3a

In the NW-German Lowlands the average field size of agricultural areas indicates the fertility of soils. Field size is relatively large on fertile soils developed on heavy loess cover SE and SW of Hannover, and on terraces of the Weser river covered by river clay soils. In contrast, less fertile podzols of the sandy uplands show smaller field sizes. (Fig. 4)

However field size can also be influenced by other conditions which is demonstrated along the border line between the Federal Republic of Germany (FRG) and the German Democratic Republik (DDR). Due to the difference in economic systems average field size in the DDR is considerably larger than in the FRG (Fig. 5).

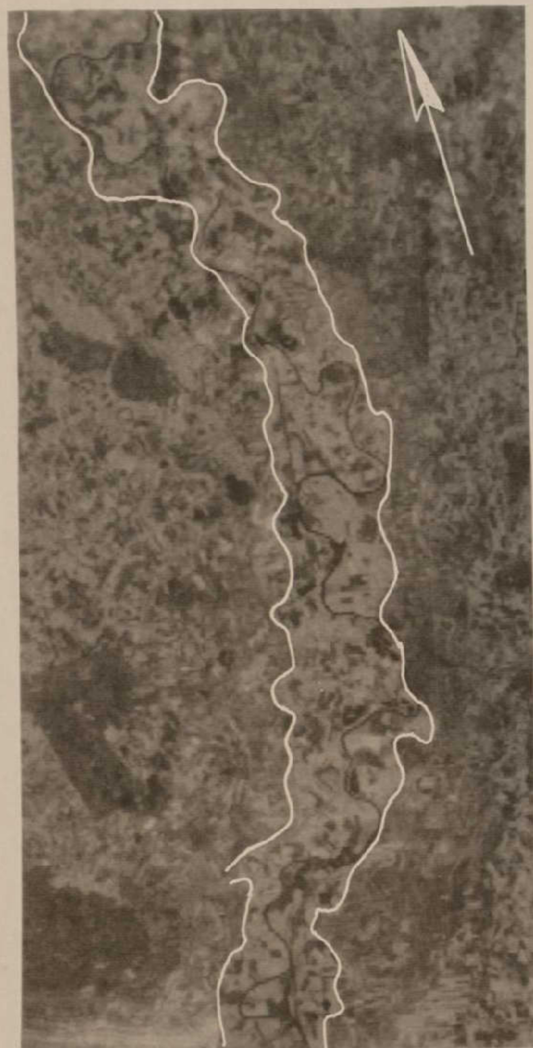
2.1.1.3. Influence of seasons on interpretability of images

The main part of ERTS-1-imagery of Germany has been taken during August, September, and October 1972. Other seasons are only represented by images of limited areas. Since conditions change only very little within short distances of less than 1 000 km even this limited material allows some judgement.

Best contrast for geological and pedological evaluation are visible on September images as described in detail in section 1.

Later in the year, by gradual change, winter conditions are approached: Pasture land is less vigorous, grass has relatively low chlorophyll content. Therefore tone in bands 6 and 7 is less bright. Fields are not freshly plowed, therefore the contrast between bare soil and vegetated areas is less pronounced. Deciduous forests appear like coniferous forests dark in bands 6 and 7. Therefore they cannot easily be discriminated from each other.

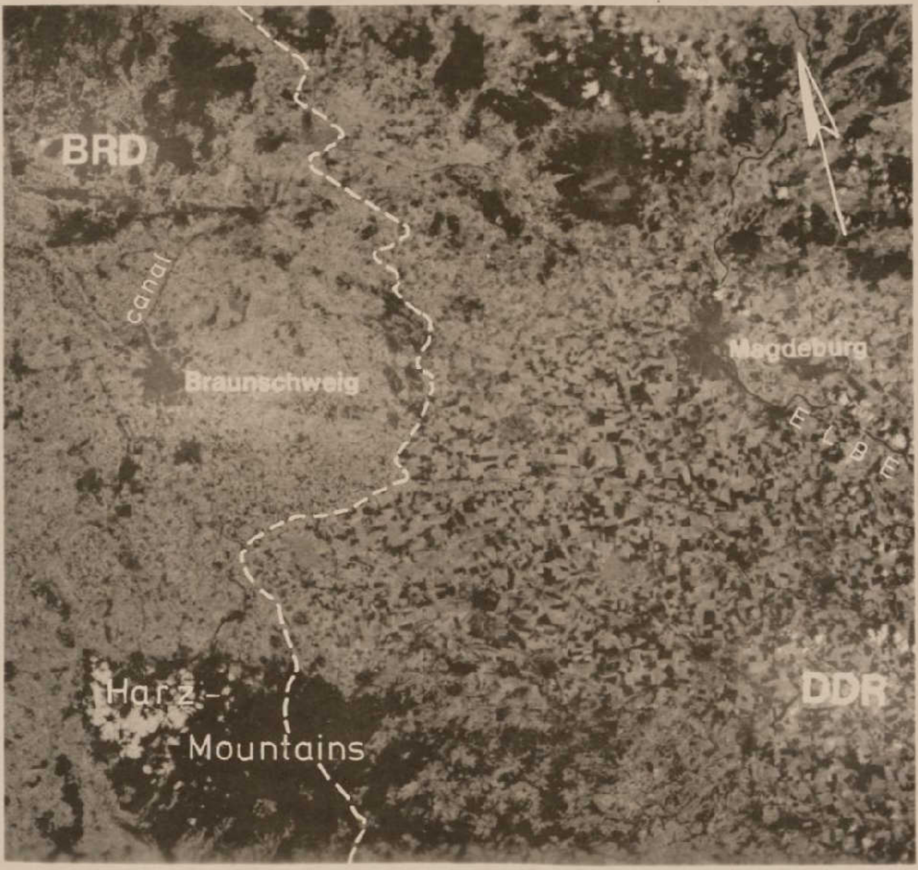
Conditions in late spring and early summer show also less pronounced contrasts than the September images for different reasons. Pasture land as well as many agricultural fields and deciduous forests with new leaves have a similar high clorophyll content and in consequence almost the same bright



0 ______ 5 km   MUEHLFELD Fig.: 4

Detail of fig. 2 showing the Weser valley with diffent soil types and related agricultural pattern

2.1-4a

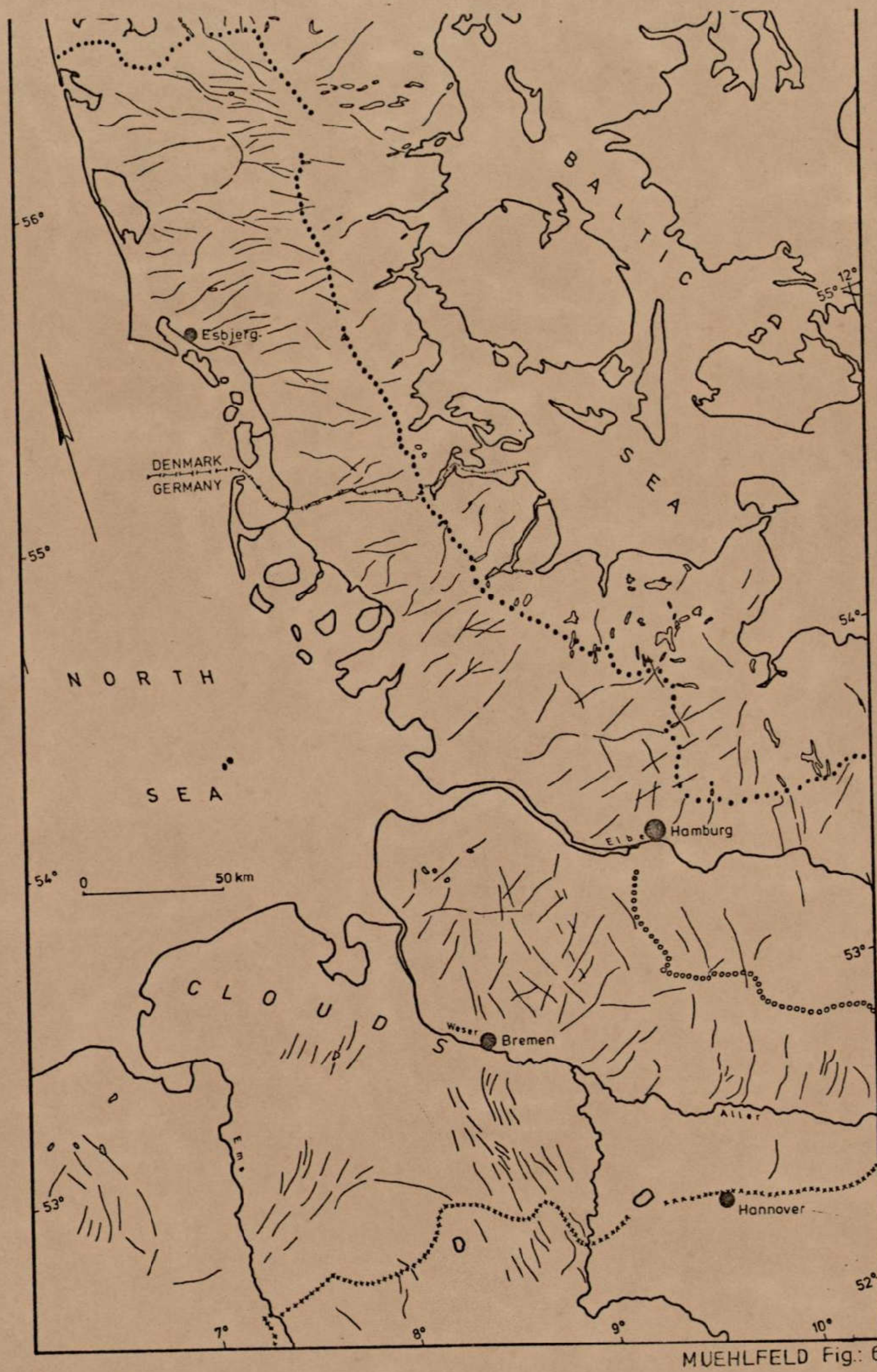


0 50km

MUEHLFELD, Fig.: 5

Detail of ERTS-1-image 1310-09432-7 showing the Harz mountais and the border area between the Federal Republic of Germany and the German Democratic Republic as characterised by different field sizes

2.1-4B



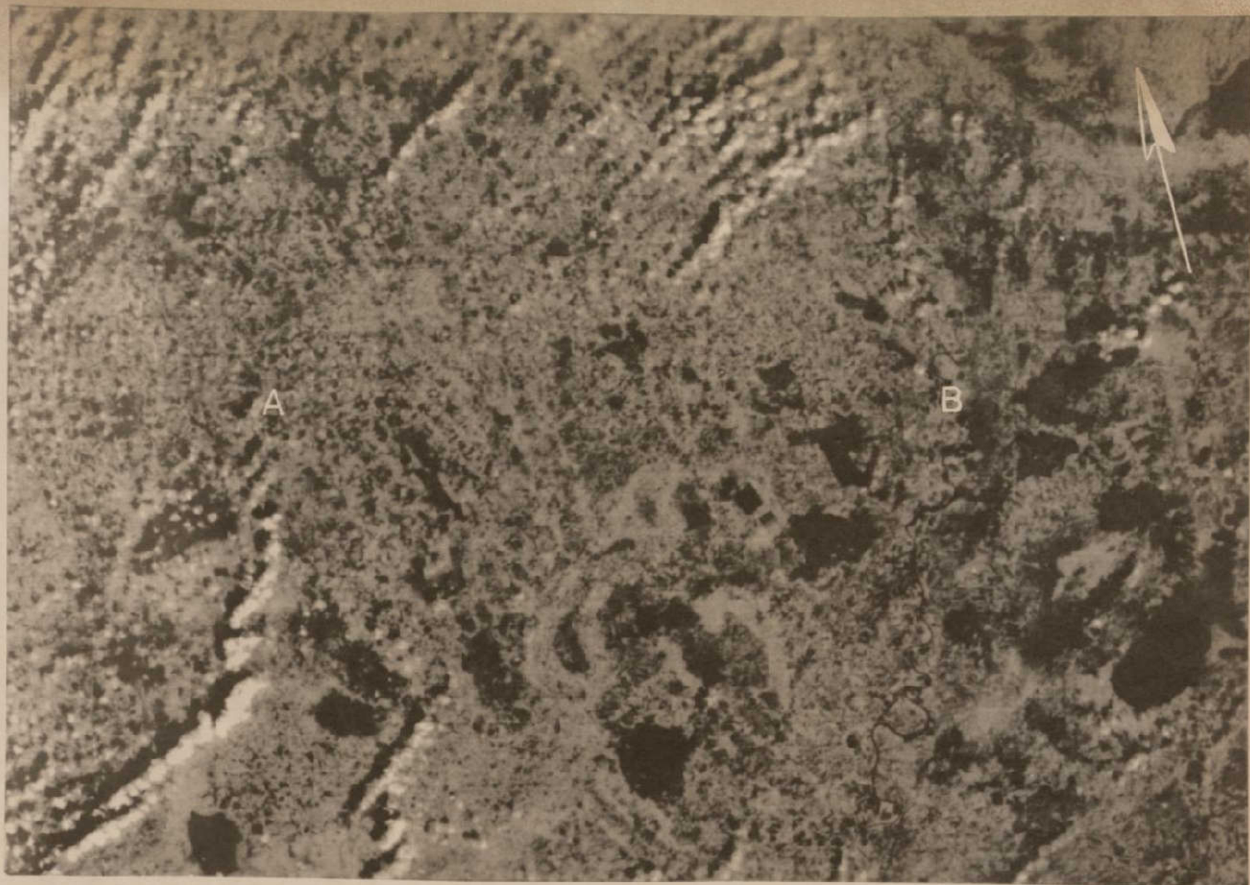
MUEHLFELD Fig.: 6

Legend

Main Ice Border Line		Weichsel-Glaciation	
" " " "	Warthe		Saale-Glaciation
" " " "	Rehburg		
Glacial drainage network			
Glacially inspired lakes			

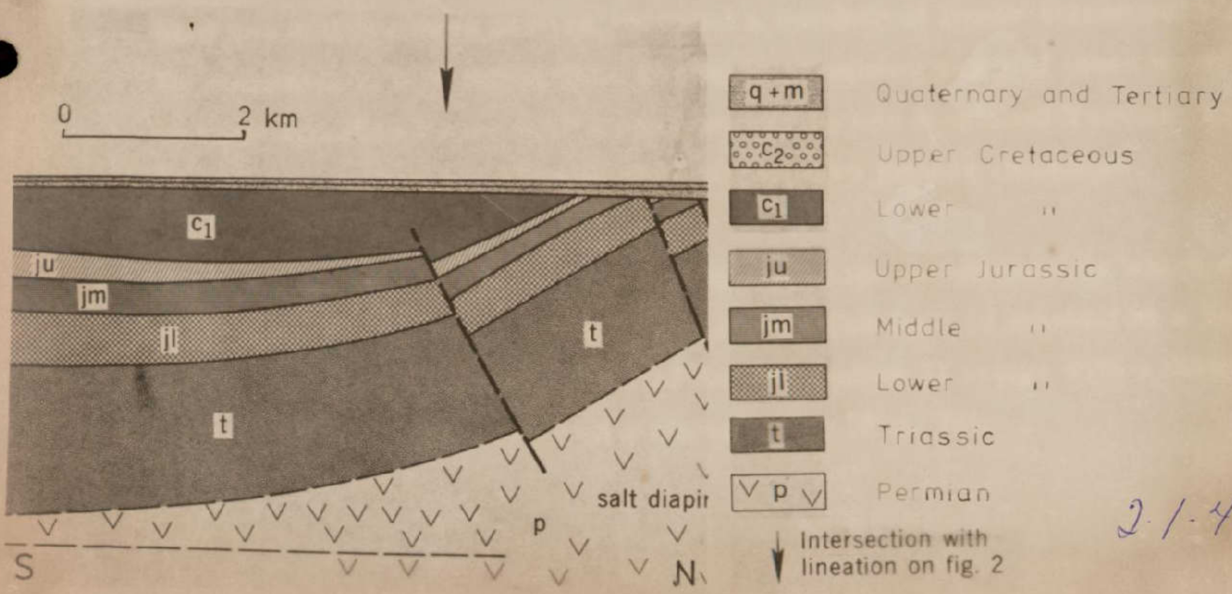
Glacial drainage networks in Northern Germany and parts of Denmark as derived from ERTS-1 images 1043-09563-7
" -09590-7
1060-09534-7
1078-09532-7
" -09535-7
1241-10003-7

2-1-4c



0 10 km ERTS-1060-09534-7 MUEHLFELD Fig.:7a

Detail from fig. 2 showing geological lineament



2·1·4d

Fig.:7b

Cross-section showing the geologic underground near the lineament of fig 7a

tone in channels 6 and 7. It is therefore difficult to differentiate between them. Even the deciduous forest is hard to detect, because bands 4 and 5 in which it should appear dark in spring tend to be too hazy for evaluation.

2.1.1.4. Glacial drainage network

In a number of regions on the imagery extraordinary dense drainage networks can be observed. Many branches of this network appear subparallel in one main direction which differs from one region to the other.

According to field check, the drainage networks consist of flat elongated depressions, only partly used by creeks or small rivers, usually too small to develop a valley of the size in which they run. Since the depressions are relatively wet, they are mainly used as pasture land.

These drainage networks probably have developed during glaciation in periods of abundant runoff of meltwater near the border of the ice. They can also be seen in Denmark (GLASAUER 1973). Fig. 6 shows their distribution in Northern Germany and Denmark.

2.1.1.5. Tectonic observations

In the imagery of the North German Lowlands very subtle indications in the land use and drainage pattern revealed a number of linear structural elements. By comparison with subsurface geophysical survey some of these were found to correspond to major fault lines covered by non displaced Tertiary and Quaternary sediments of up to several hundred meters thickness.

Field check gave in one case an indication of the mechanism by which such a fault line can indicate itself at the surface. The fault is marked by a number of dark patches in bands 6 and 7 of the September 21 image with a diameter of 0,5 to 1 km. They make up a straight line (Fig. 7a).

0 25 km MUEHLFELD, Fig.: 8a

Detail of ERTS-1 image 1076-09424-5 showing the area South of the Harz mountains with mesozoic formations building the Thuringian Basin

0 25 km Fig. 8b

Geolog. map showing the same area as fig. 8a

2-1-5a → Forested areas, covering outcrop of triassic
→ limestone indicating basin structure

According to field check two of these patches consist of small forests. The others (about 20) are areas of agricultural fields with a high proportion of freshly plowed fields. They contrast with their environment because they are partly surrounded by very subtle, mostly narrow depressions used as pasture land. Also a dense drainage network of many subparallel branches (see section 4) which crosses the line in an oblique direction shows many anomalies along the line (confluents, changes in width).

A seismic cross-section shows the lineation following the down thrown block of a fault (Fig. 7 b). Experiences in other sedimentary basins suggest that differential compaction of sediments in the upthrown and the downthrown blocks has caused a slightly greater subsidence in a narrow zone following the downthrown block (MÜHLFELD 1968).

In some cases structural information can be derived from the outcrop pattern of certain rocks. In the Thuringia Basin for instance, outcrop of Triassic limestone (Muschelkalk) is marked by a dense cover of deciduous forest. The outcrop pattern shows the syncline character of the structure with anomalies caused by faulting (Fig. 8a and b).

2.1.1.6. Conclusions

The study of geologic and pedologic interpretability of ERTS-imagery in Central Europe has shown the importance of analysis and interpretation of vegetational land use. With necessary care the experiences can be applied in less known areas of similar climate.

The important improvement of our knowledge on linear tectonics by ERTS has stimulated combined studies of ERTS and geophysical investigations for the prospection of ore deposits in Germany now under way.

Cited Literature:

GLASAUER, G.: Mitteleuropa im Satellitenbild, Nutzungspersepktiven am Beispiel der ERTS-1-Bilder. - Zulassungsarbeit, Geographisches Institut der Universität Heidelberg, 1973.

MÜHLFELD, R.: Photogeologische Beobachtungen zum Sedimentaufbau und zur Tektonik im ostbayerischen Molassebecken zwischen Landshut und Eggerfelden. - Geol. Jb. 85, S. 285 - 298, Hannover 1968.

2.1.2. Structural Analysis and Lithological Mapping of the Premesozoic and Mesozoic Units of Germany by P. KRONBERG - Geological Institute of the Technical University - Clausthal

2.1.2.1. Objective of the Project

Structural analysis and lithological mapping of the premesozoic and mesozoic units of Germany. Correlations with known geological data.

2.1.2.2. Scope of Activity

The structural and lithological evaluation of the ERTS-images obtained in the 1972/73 period has been performed by applying conventional photogeological techniques. Maps of surface structures of the major part of Germany have been compiled from ERTS-data at a scale 1 : 1 000 000. An ERTS-mosaic has been compiled covering Central Europe.

2.1.2.3. Analysis, findings, techniques

2.1.2.3.1. Image Quality and Interpretability

The MSS-imagery received covers all areas of the premesozoic uplands of Germany. The image quality has been somewhat variable due to local or regional haze or cloudiness. Mostly, the image quality is good. The imagery received includes black and white paper prints and black and white transparencies. 2-Color composites have been received covering the Harz and the Thüringer Wald/Fichtelgebirge and the adjacent areas. No repeated coverage has been received for the individual areas of interest.

Channel 4 imagery, in general, has proved to be of low value for lithological and strucutral mapping because of haziness, low contrast, poor resolution and too dark grey tones.

Combinations of channels 4 and 6 or 7 have proven to be most useful for the geological evaluation because of better contrast and better resolution. Not much additional information could be drawn from the color composites in comparison to the data obtained from single band prints (black and white).

2.1.2.3.2. Techniques

Conventional photogeological techniques have been applied.

2.1.2.3.3. Findings

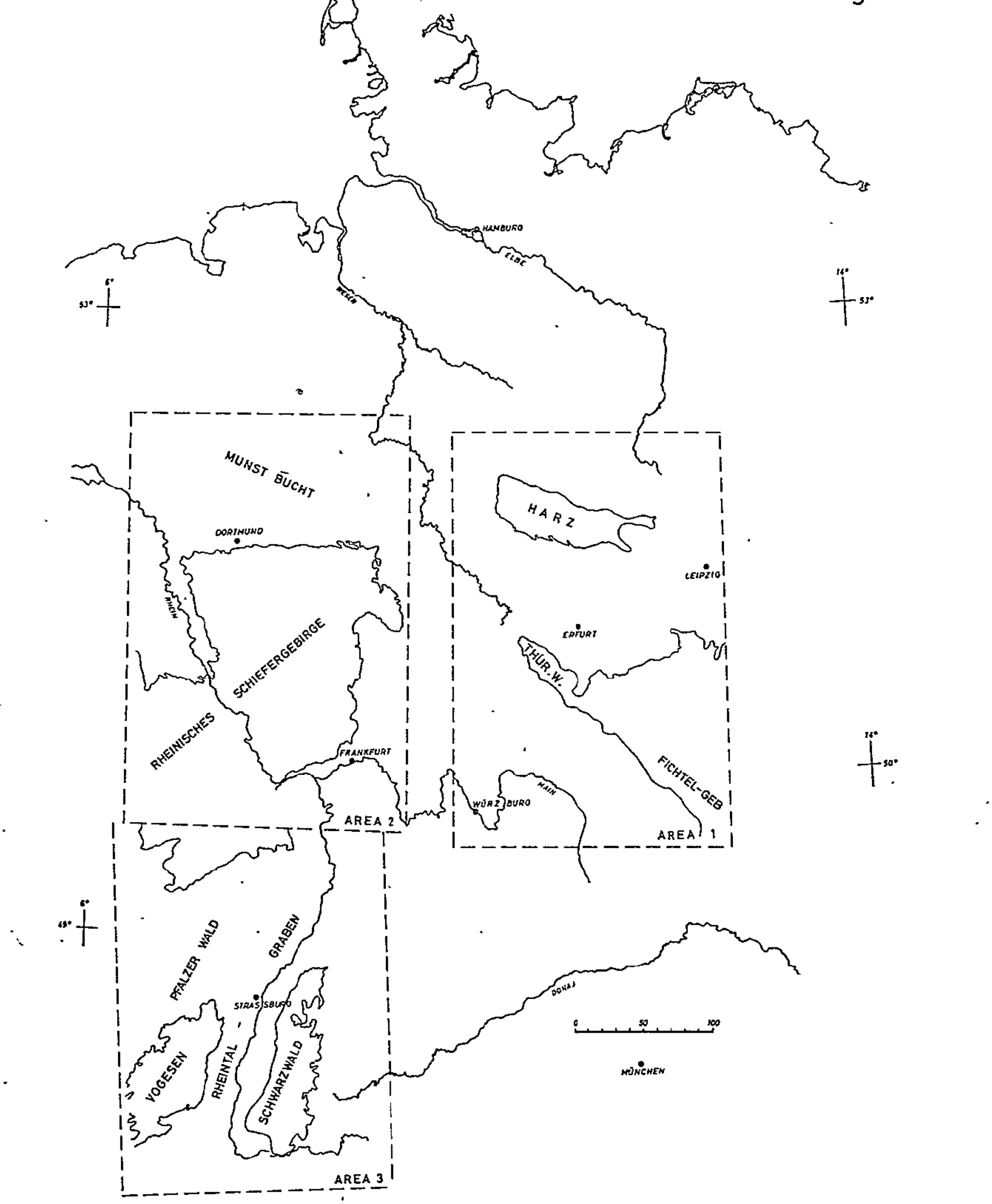
2.1.2.3.3.1. Structural Analysis.

The uplands of Germany (Harz, Thüringer Wald, Fichtelgebirge, Rheinisches Schiefergebirge, Schwarzwald) and the surrounding lowland areas have been screened for fracture traces. While the uplands are mainly underlain by folded palaeozoic strata, the lowlands in general are underlain by mesozoic and tertiary rocks, unfolded but locally effected by block-faulting.

A Geological Map of the Federal Republic of Germany (Scale 1 : 1 000 000) was published in 1973 based on detailed geological field investigations carried out over decades. The question was, if ERTS-type imagery at the same scale would provide us with additional information on the structural setting of the upland areas and the adjacent lowlands. Of interest were the locations, the frequency and the orientation of the fracture traces mapped on ERTS-images. For 3 study areas, the positions of which are shown on Fig. 1, the known structural data, as taken from the 1973 map, were compared with the structural data obtained from the evaluation of the ERTS-images.

Area 1 (Fig. 2 and 3) includes the Harz mountains in the North and the uplands of the Thüringer Wald in the South. Both mountain areas as well as the Fichtelgebirge in the Southern part of the area, are made up of palaeozoic strata which were folded during the variscian orogeny. Locally, igneous intrusions occur. The basin area around Erfurt (Thüringer Becken) is mainly underlain by unfolded mesozoic strata. A comparison between the known structural data (Fig. 2) and the structural data obtained from the ERTS-images (Fig. 3) clearly demonstrates that the structural setting of the upland areas is much more complex than it had been thought so far. That refers to the numbers of fractures as well as to the azimuths of the individual fracture sets. Up to now, faults and fractures of the socalled hercynian trend, striking around 30^{o}, were believed to predominate in the structural pattern of the Harz and the Thüringer Wald. Fig. 3 shows intense fracturing along N/S-, NE- and ESE-directions as well.

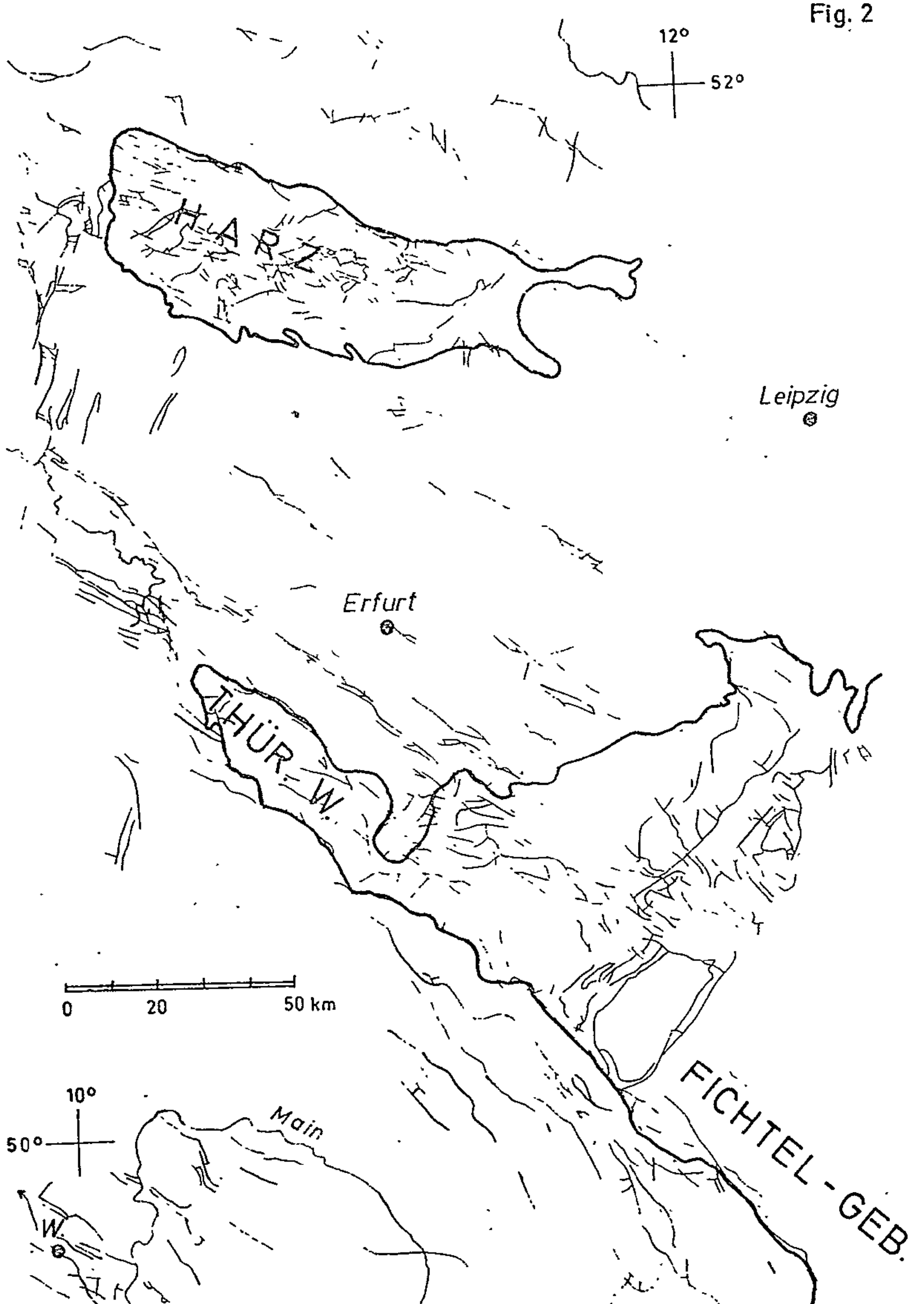
Fig. 1



KRONBERG, 1974

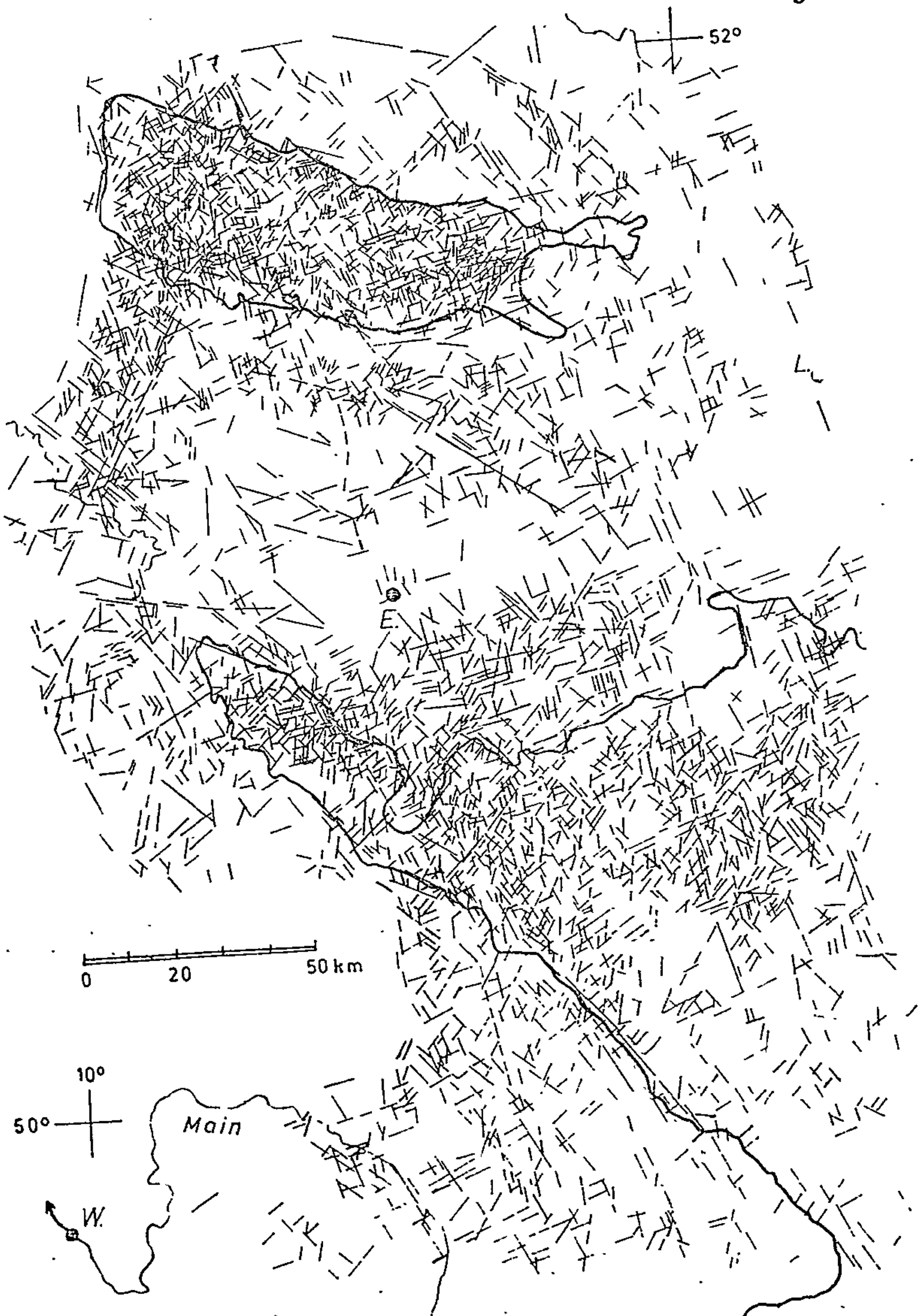
2-1-9a

Fig. 2


12°
52°
HARZ
Leipzig
Erfurt
THÜR. W.
FICHTEL-GEB.
0
20
50 km
10°
50°
Main
W.
KRONBERG 1974

2-1-9-B

Fig. 3



KRONBERG 1974

Fracture sets of equal orientation could also be mapped in the lowland areas between the Harz and the Thüringer Wald. Within the lowlands the 1973 map shows only a small number of faults running mainly NW/SE. Fig. 3 demonstrates that the lowlands are cut by a much more complicated fracture pattern. Structural maps published so far do not show the fracturing along the ENE- and NNW-trends. It has to be emphazised, that the individual fracture trends are very persistent and that fractures of the predominating trends cut through the upland as well as through the lowland areas.

Area 2 (Fig. 4 and 5) includes the Rheinisches Schiefergebirge and the socalled Münstersche Bucht (Munster Basin). The Rheinisches Schiefergebirge is underlain by palaeozoic strata folded during the variscian orogeny. The palaeozoic units continue Northward underneath the Münstersche Bucht, where they are covered by several hundred meters of cretaceous rocks. A comparison of Fig. 4 and 5 demonstrates the wealth of additional structural information obtained from the ERTS-images. While the two trends of fracturing and faulting shown on the 1973 map were confirmed by the ERTS-data, several other trends of intense fracturing could be mapped on the ERTS-images. It is of special interest, that these fracture sets follow the same azimuths as the fracture sets cutting through the uplands and lowlands of area 1 (Fig. 3).

Most striking are the results from ERTS-mapping within the area of the Münstersche Bucht. Here, the Geological Map of 1973 does not show any fault line. However, the evaluation of the ERTS-images reveals that the unfolded mesozoic strata of the Münstersche Bucht are cut by several sets of intense fracturing along the azimuths predominating within the fracture pattern of the Rheinisches Schiefergebirge in the South. This means that the fracturing of the folded palaeozoic strata below the thick mesozoic cover of the Münstersche Bucht has been reactivated and propagated upward and controls the fracturing and faulting of this area of intense industrialization and underground mining. This fact was previously unknown.

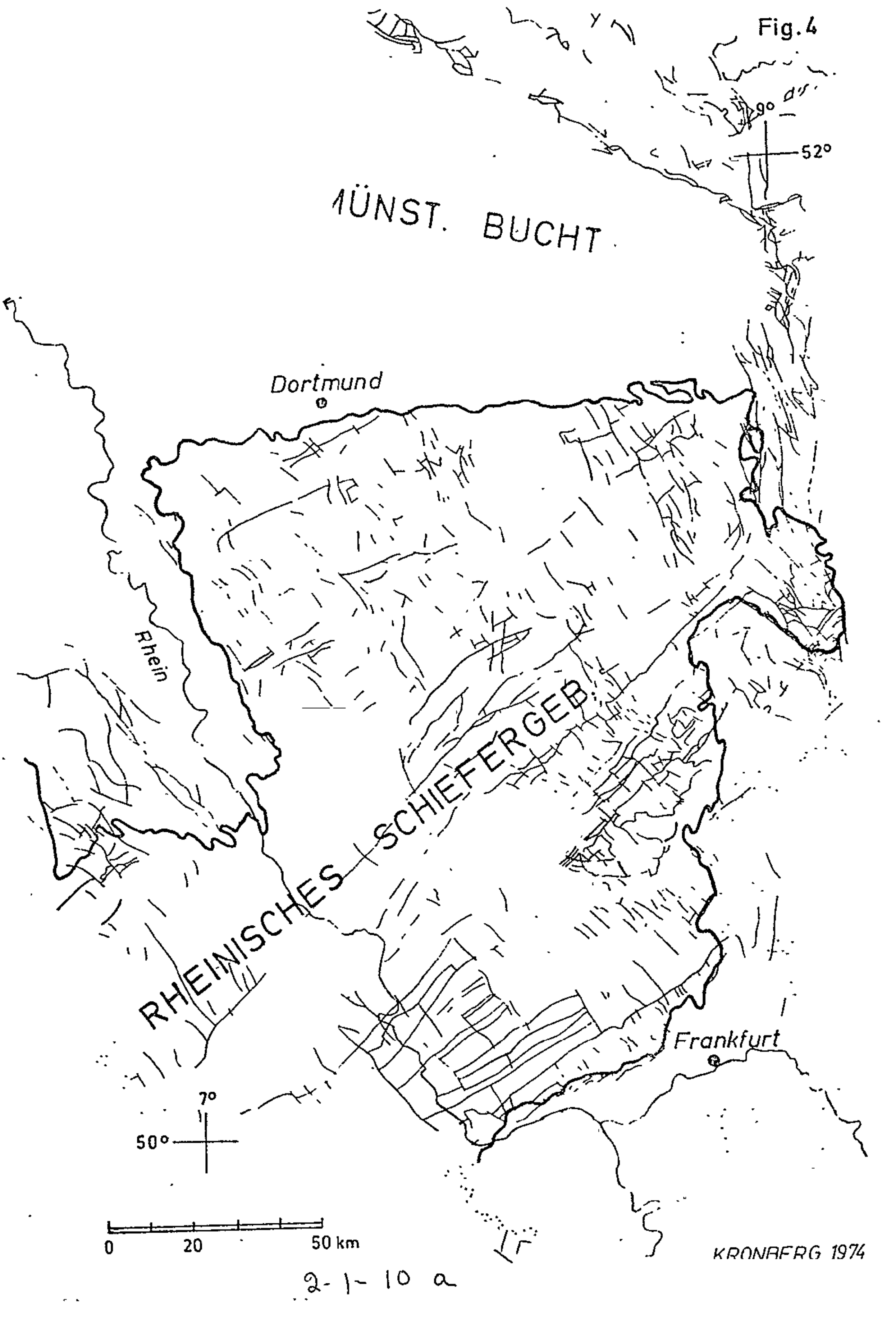


Fig. 4
9°
52°
MÜNST. BUCHT
Dortmund
Rhein
RHEINISCHES SCHIEFERGEB.
Frankfurt
7°
50°
0
20
50 km
KRONBERG 1974

2-1-10 a

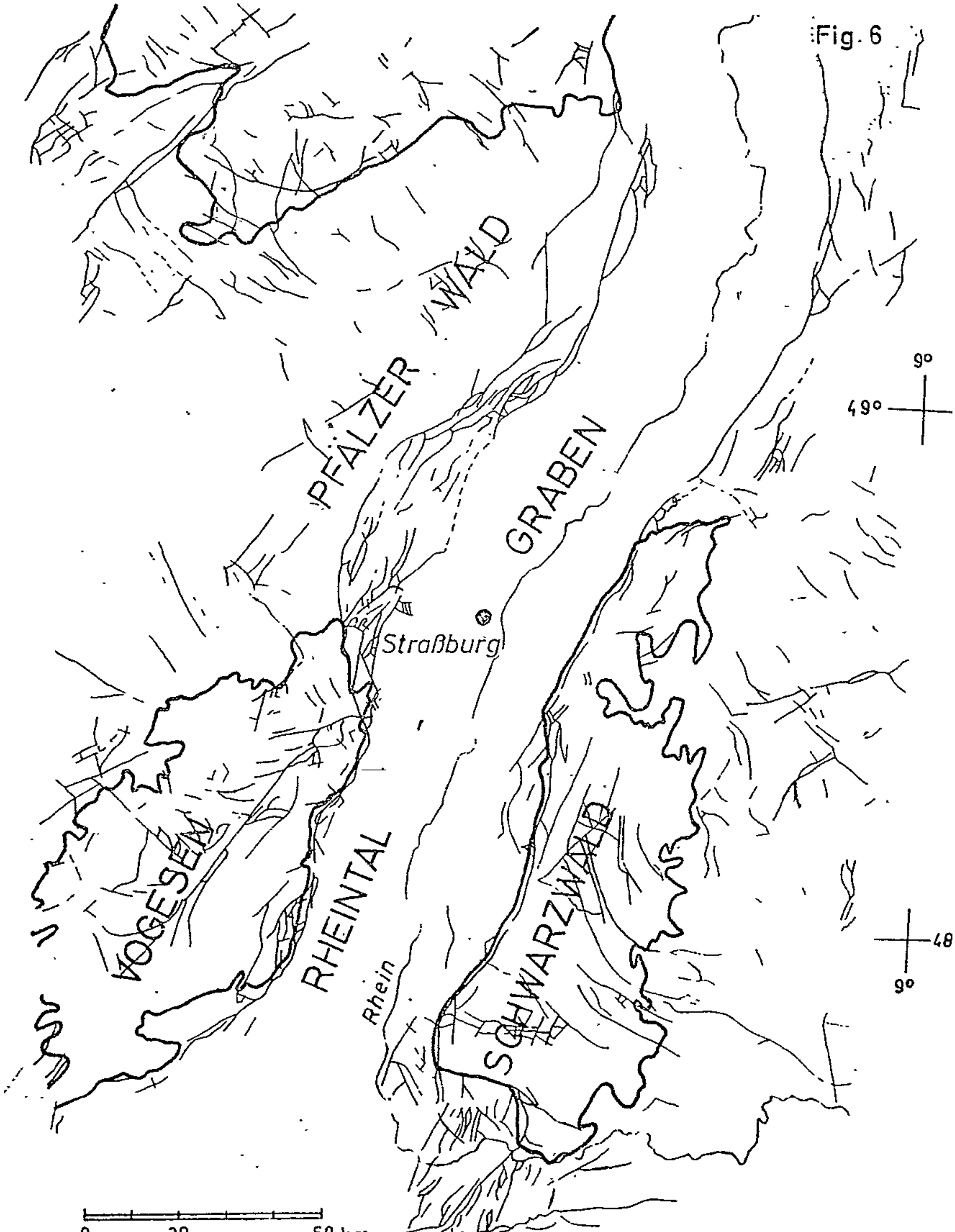
Fig. 5

2-1-10 B

Area 3 (Fig. 6 and 7) includes the upland areas of the Schwarzwald and the Vogesen (belonging to France), uplifted palaeozoic blocks flanking the Rheintal-Graben, which is filled with several thousand meters of mesozoic and tertiary deposits. The comparison of the data shown in the 1973 map with the data obtained from ERTS (Fig. 7) shows a good correlation between the major fault structures which were known, and the fracture traces mapped on the ERTS-image. But according to the ERTS-data, the fracturing is much more intense than shown on maps published previously. This refers in particular to the NNE-striking fractures running parallel to the general trend of the Rheintal-Graben but also to fracture sets striking NNW and ENE. Results from drilling in the Graben-area indicate block-faulting within the Graben. But no surface traces of faulting are shown in any of the published maps within the Graben-area. On the ERTS-images fracture traces could be mapped all over the Graben area. Of special interest is the fact that only a smaller number of fracture traces mapped on ERTS-imagery run parallel to the NNE-trend of the Graben. A larger number of fracture traces follow the azimuths of fracture sets predominating in the adjacent upland areas of the Schwarzwald and the Vogesen. Obviously, the fracture pattern which developed along with the formation of the Rheintal-Graben is superimposed by an older fracture pattern of the basement (up to several thousand meters below younger sediments) which has been projected upwards by reactivation. Again, a good correlation can be found between the trends of fracturing of the areas 1, 2, and 3.

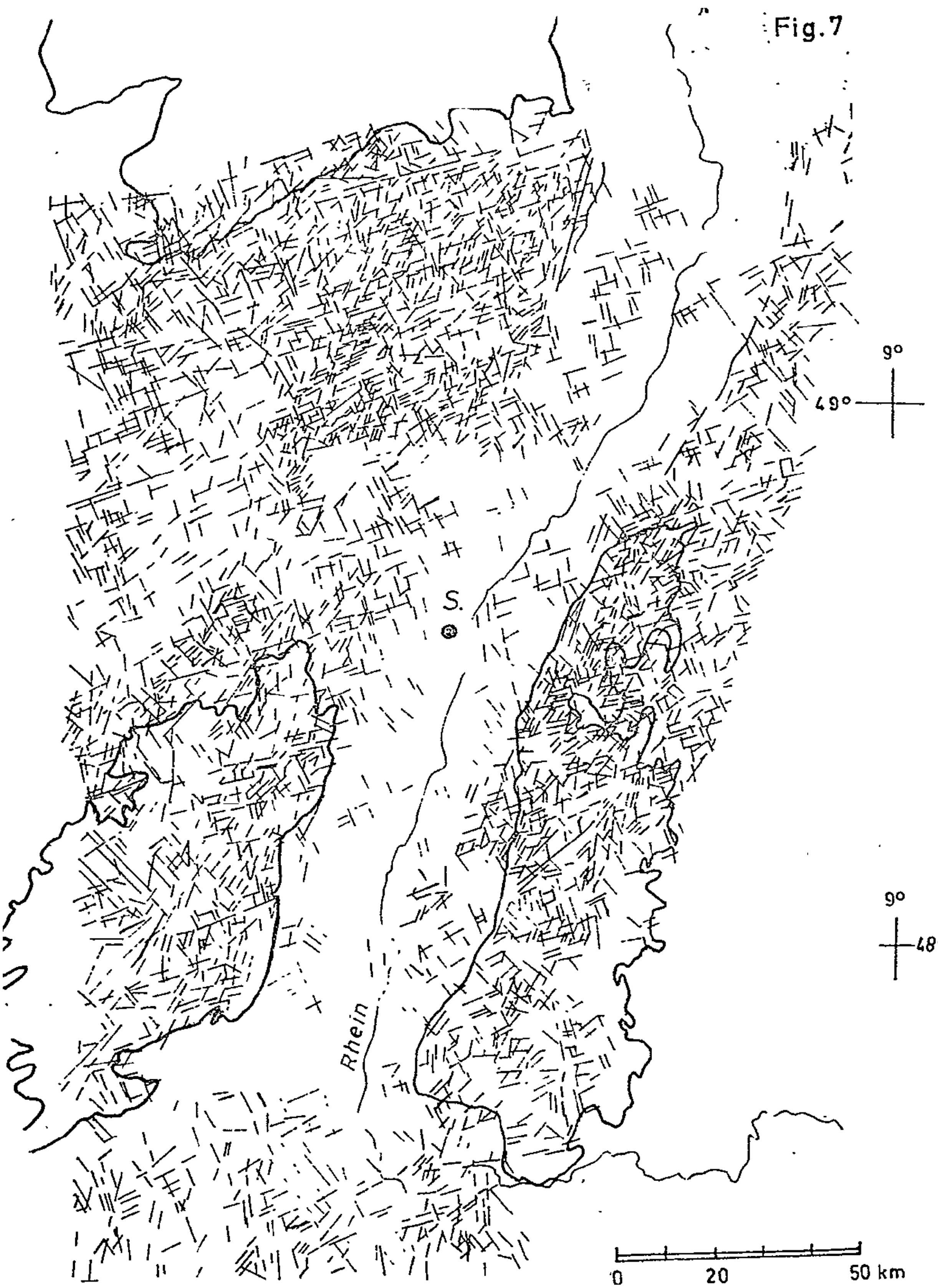
2.1.2.3.3.2. Summary of the ERTS-investigation and related projects

Even for a geologically well known area such as Germany ERTS-images have proved to be a very useful tool for regional structural analysis. A comparison of structural data obtained from the evaluation of ERTS-imagery with a recently (1973) published Geological Map of the Federal Republic of Germany (Scale 1 : 1 000 000), clearly demonstrates how much new information could be obtained on the structural setting (fracture patterns) of Germany's major upland areas and the adjacent low lands. This refers to the distribution, the frequency/area and to the azimuths of the fracturing. It should be mentioned, that no identification of the directions of movement along identified faults, could be obtained from the ERTS-images.



KRONBERG 1974

2-1-11 a



KRONBERG 1974

2. 1- 11 B

Within the upland areas, underlain by folded palaeozoic strata, a large number of additional fracture traces have been found following known predominating trends (N/S, NW/SE, SW/NE). Even more important, a large number of fractures could be mapped on ERTS-images following so far less known or unknown trends within the upland areas (ENE, NNE, E/W). The known ore deposits of the uplands are mostly structurally controlled. Therefore an investigation will be started to survey a possible relationship of the structural data obtained from ERTS with the mineralization of the palaeozoic uplands.

Most striking results were obtained within the lowland areas, which are underlain by mesozoic and tertiary strata, locally with quaternary deposits on top of them.

Within the area of the Münstersche Bucht, for instance, no faulting or fracturing has been shown on any of the published maps. The evaluation of the ERTS-images revealed intense fracture patterns of azimuths equal to the ones observed (on ERTS-images) within the Rheinisches Schiefergebirge South of the M.B. The folded palaeozoic strata of the Rheinisches Schiefergebirge continue Northward under the Münstersche Bucht. There, under a thick cover of mesozoic strata, they contain the coal measures of the "Ruhrgebiet". Here the coal mining and the extension of mining operations is very much affected by or dependent on tectonic structures. A team of the Clausthal Institute has been working for years within the mines investigating the local and regional tectonic structures. The correlation of ERTS-data with the data from the underground investigations will be of great interest for mining operations of the future. Therefore a project has been started to correlate the surface structures of fracturing as mapped on ERTS-images with the structural data from underground investigations.

The map of surface structures obtained from ERTS-imagery, reveals that fracture sets of various azimuths are very persistent all over the mapping area. The predominant fracture sets are found in upland and lowland areas alike. This indicates that an old fracture pattern reflecting basement tectonics, is being superimposed on fracture patterns, which have to be related to stress of the variscian orogeny and to younger tectonic events during the Mesozoicum and the Tertiary such as blockfaulting, formation of graben- and horst-structures. The fracture map compiled from ERTS-data, provides us with a new picture of the structural setting of Germany and Central Europe. Therefore a project has been initiated to investigate the fracture pattern of the uplands and lowlands in more detail with regard to azimuth, frequency/area and continuance of individual fracture sets or lines. The results of these investigations are to be compared with the present concept of the structural development of Germany and Central Europe. Of special interest will be the age of the individual fracture sets. The results of the above investigations will be correlated with the results from similar investigations covering areas in Greece, Turkey and Scandinavia (and Ethiopia). The purpose of these other investigations is to find out which continental and global fracture sets exist and which geomechanic forces might have caused them.

2.1.2.3.3.3. Lithological analysis

In the test area - with presently temperate humid conditions and warm humid conditions during the Tertiary - the lithology is rarely well expressed. Intensive weathering, intensive land use and cultivation, and urbanization cause surface conditions very unfavourable for lithological mapping on aerial photographs as well as on ERTS-images for most parts of Germany. Larger land units only show up by contrasts in morphology, land use and vegetation. Whereas the larger lithological and structural units of Germany are quite obvious at first glance on ERTS-imagery or the ERTS-mosaic compiled for Central Europe, it is rather difficult or - in most cases - impossible, to outline individual lithological units accurately. No common criteria have been found allowing

the mapping of specific lithological units over a larger area such as covered by an ERTS-image. A comparison with the Geological Map of Germany, published in 1973 (Scale 1 : 1 000 000), does not reveal any new information on the lithology of the studied upland and lowland areas. Therefore, ERTS-imagery has not proven to be useful for lithological mapping in the test area. It has to be mentioned, of course, that only one ERTS-image has been received for each individual scene. Repeated coverage(ERTS-images taken at various seasons), would surely provide us with a better basis for regional lithological mapping.

2-1-14a KRONBERG, 1974 Fig 8

2.1.3. Relationship between the tectonic of Lineaments and Ore districts in the Eastern part of the Rhenish Massif compiled from interpretation of ERTS-imagery by P. HOPPE - Federal Geological Survey - Hannover

2.1.3.1. Preface

This investigation is concerned with the interpretation of photolineations which were grouped into fault zones and then related to known ore deposits. The result show that with the aid of Satellite imagery larger relationships become more obious and as a result are more easily interpreted.

In this way the tectonic importance of the Rhenish (NNE-SSW) striking Siegen-Soest lineament was confirmed in principle and its direction precisely noted and elongated. In addition the close relationship to ore deposits became clearer. The same applies for an Eggish (NNW-SSE) striking lineament along the Lower Rhine and the area of its intersection with the Siegen-Soest lineament.

These facts reveal new indications concerning the possible prolongation of ore bearing zones which will prompt further efforts to select prospection areas in the Eastern part of the Rhenish Massif. The knowledge gained here is at present being evaluated for a non-ferrous metal search which at the moment is being conducted by a consortium of State departments and also for the German industry.

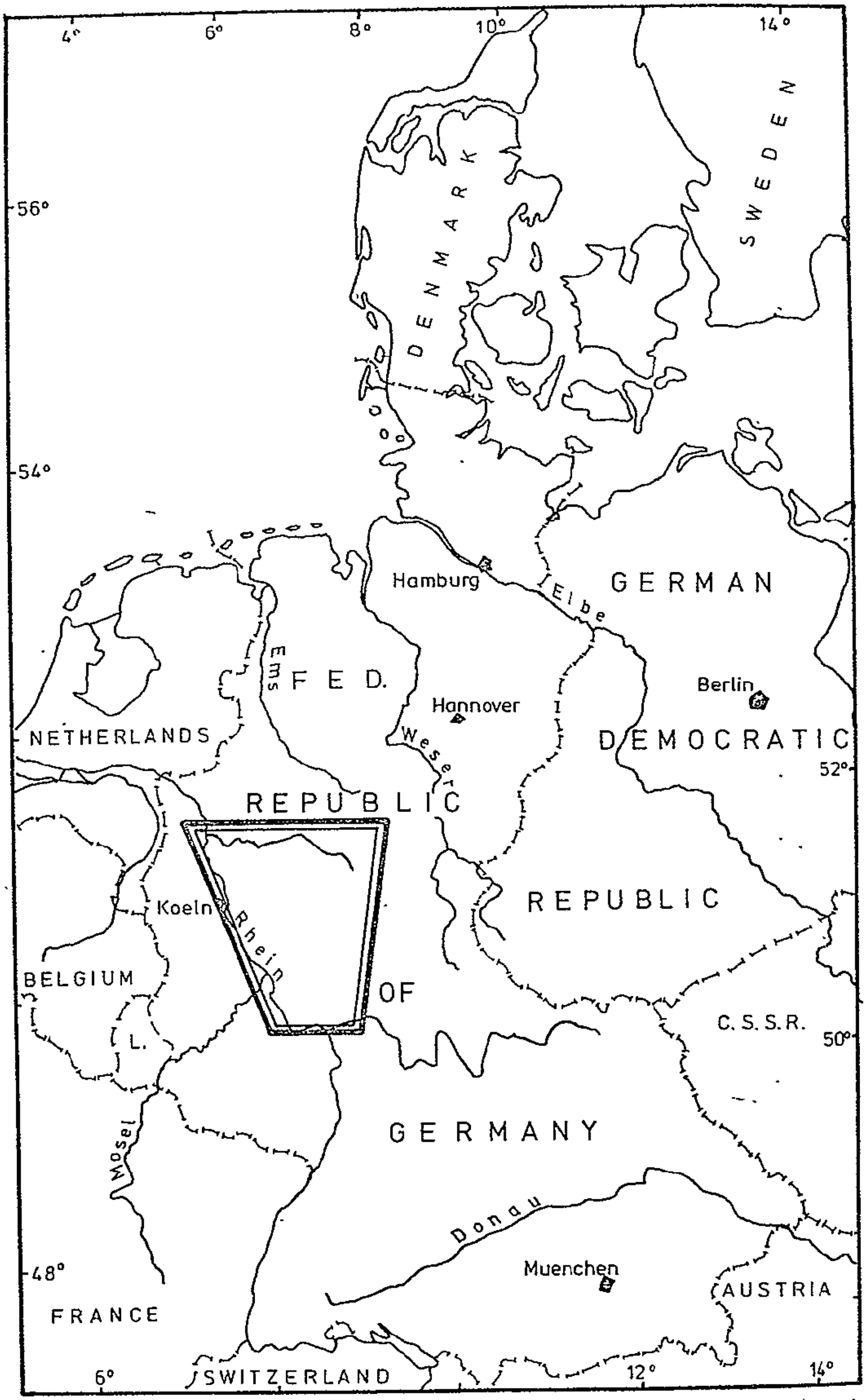
2.1.3.2. Area of Investigation

The test area is limited to the Eastern part of the Rhenish Massif (see fig. 1). Three ERTS-1 images (MSS channel 7 only) were interpreted:

a) NW-Corner = Image Nr. 1043-09595, taken 04.6.1972, Cloud cover 20 %

b) N-Part = Image Nr. 1060-09540, taken 21.9.1972, Cloud cover 30 %

c) S-Part = Image Nr. 1060-09543, taken 21.9.1972, Cloud cover 20 %



Area of Investigation

Hoppe, Fig.: 1

2.1-15.a

Despite the 20 - 30 % cloud cover the interpretation was only slightly affected as the larger cloud banks were confined to the lowlands and only a small amount of cumulus hung above the highest features of the Massif.

The Eastern part of the Rhenish Schiefergebirge that consists mainly of Paleozoic rocks is contained, in the North by the Cretaceous rocks of the Munster Basin, in the East by the Lower Mesozoic and Tertiary rocks of the Hessian Depression, in the South by Tertiary and Quaternary rocks of the Upper Rhine Graben, in the West by Tertiary and Quaternary rocks of the Lower Rhine and the bridge of Paleozoic rocks of the Middle Rhine.

2.2.3.3. Course of the Investigation

To begin with, the photolineations visible on ERTS-1 imagery were extracted. They reflect vegetation borders and land forms such as straight river lines and hill chains. Due to past forestry and agricultural land use the field and wood borders of today are in the main related to the lithological features of the soil and bedrock (see also the contribution by R. MÜHLFELD in this report). They signify in this way definite borders of the underground whether they are stratographic-lithological differences or tectonically influenced material borders and breaks.

The net of mainly short pholineations were graphically divided into their different directions as follows; the photolineations were extracted over the whole area in ten degree sectors using a different colour for each of the 18 sectors. The fault zones were then easily constructed. The necessary care was taken, particularly with elements striking parallel to the Variscian fold axis of the Massif. The elements were traced with reference to the representation shown on the Geological Map of Nordrhein-Westfalen (Scale 1 : 500 000, in print). The fault zones so discovered were then overlayed onto the detailed Mineral Map II of Nordrhein-Westfalen (Scale 1 : 500 000 by STORK et al., 1973). This revealed a remarkable similarity of direction between the ore lodes, and fault zones and also

a marked accumulation of lodes at some of these faults. As a result seemingly promising sections of these zones can be extracted for prospection.

2.1.3.4. Results

2.1.3.4.1. Photolineations

The photo interpretation produced a map of the photolineation network (Plate 1; see also the contribution to this report by P. KRONBERG, Geological Institute TU Clausthal-Zellerfeld). Within the limited area of an ore district a marked similarity of direction between the individual lodes and photolineations was evident. Lodes and photolineations lie more or less parallel to, in part, wide angled crossing fault zones (See the Lead/zinc districts Bensberg and Nassau).

The use of improved techniques, for satellite photographic enlargement (Magnetic tape play instead of photographic enlargement) and for the projection of the satellite photograph onto a map base, should result in a more accurate comparative cover. This is most important for a small scale lode prospection such as is at present in progress in the Bensberg ore district. It is there, with the assistance of geoelectric measurements, that faults were located that were not obtained by geological mapping. These faults can, without difficulty, be compared with photolineations (a friendly verbal tip from VOGELSANG).

2.1.3.4.2. Fault Zones

To present more clearly the tectonic division of the Rhenish Massif and in particular to establish the larger, prolongated faults, fault zones were extracted from the dense network of photolineations in the manner described

above (Plate 2). These fault zones have the following characteristics:

a) They can be traced for tens of kilometers, in some cases for over a 100 Km,. in a more or less straight line, with a relatively narrower width of mainly up to 1 Km.

b) The main directional trend lies approximately NNE-SSW (= Rhenish direction) and NNW-SSE (= Eggish direction). Then come the following directions: NW-SE (= Franconian), cross faults to the general Erzgebirgish striking fold axes, WNW-ESE (= Hercynian) and SW-NE (= Erzgebirgish).

c) The fault zones are not limited to the Variscian Massif. They cut straight through its border and can be followed further in younger cover sediments. This can be clearly seen at the Northern border with the Cretaceous sediments of the Munster Basin. In particular they influence the Western and Eastern borders of the Massif.

d) The fault zones traced from photolineations confirm and correct longer fault zones that previously, could only in part, be postulated on the basis of their lithological, tectonical or mineral depositional peculiarities (See A. PILGER, 1957). In particular, however, they prolongate these zones in their length and bring to light additional zones.

e) Very often lode deposits are related to these fault zones particular in the area of the cross points of the longer fault zones.

With the development of the present fault network in the Eastern Rhenish-Massif periods of quiet alternated with periods of intense activity. For the Variscian folded Massif the decisive stamping occured at the end of the upper Carboniferous after, from Devonian to Carboniferous, increasing orogenic disturbance, mainly with fold axis parallel, extended thrust faults in a SW-NE direction (= Erzgebirgish) and NW-SE striking cross faults (= Frankish). One can today assume that these cross faults were exaggerated in the older mapping. For this reason G. RICHTER-BERNBURG (1974)

calculated the unusually high percentage of 89 % NW-SE faults in the Rhenish Schiefergebirge.

Due to the dense vegetation cover it was overlooked for a long period of mapping, that next to the initiation of the Variscian Orogenesis but particularly during the later faulting that the underground was divided into NNW-SSE, NNE-SSW and WNW-ESE directed fault systems. These systems have been brought to light in large numbers due to the wider scope made possible by Satellite imagery. It is just these fault systems that are of particular importance to the developement of the different ore lodes.

These fault zones also are considered as likely ground water carriers in some areas. After measurements of ground water runoff at bore wells in the Hessian portion of the Rhenish Schiefergebirge (in the area to the Southeast adjoining the test area) W. STENGEL-RUTKOWSKI (1969) were able to prove that the higher and more regular water yield came from Hercynian and mainly Rhenish directed faults. He traces the breaking open of these faults, which are limited to definite zones, back to expansion that took place mainly in the Upper Tertiary and Lower Pleistoncene and are today still tracable.

2.1.3.4.3. The Siegen-Soest Lineament

A. PILGER (1957) along with other authors, attached great importance to the Rhenish structures in the investigated area and based on paleogeographic and mineral depositional finds in a zone running through Siegen and Soest, he suspects a rupture, the roots of which are imbedded in the deep basement and which during the developement of the Rhenohercynian Geosyncline apparently revealed itself as a disturbing element:

a) This zone limits acies areas during the orogenetic developement of the Geosyncline (A. PILGER, 1957, Fig. 2; E. PAPROTH & M. WOLF, 1973, Figs. 8-11).

b) In the Devonian and Carboniferous rocks of the Massif the highest degree of carbonification and deviation of isolines of equal carbonification occur in this zone (E. PAPROTH & M. WOLF, 1973, Figs. 4-7).

c) The geomagnetic measurements show curves of total intensity that turn on this zone (W. WOLFF, 1957, Fig. 1; Aeromagnetic Map of the BRD by D. EBERLE, 1973).

d) In this zone are concentrated Devonian Keratophyr, and Carboniferous Diabase and also the Tertiary Basalts of the Westerwald (Westerberg).

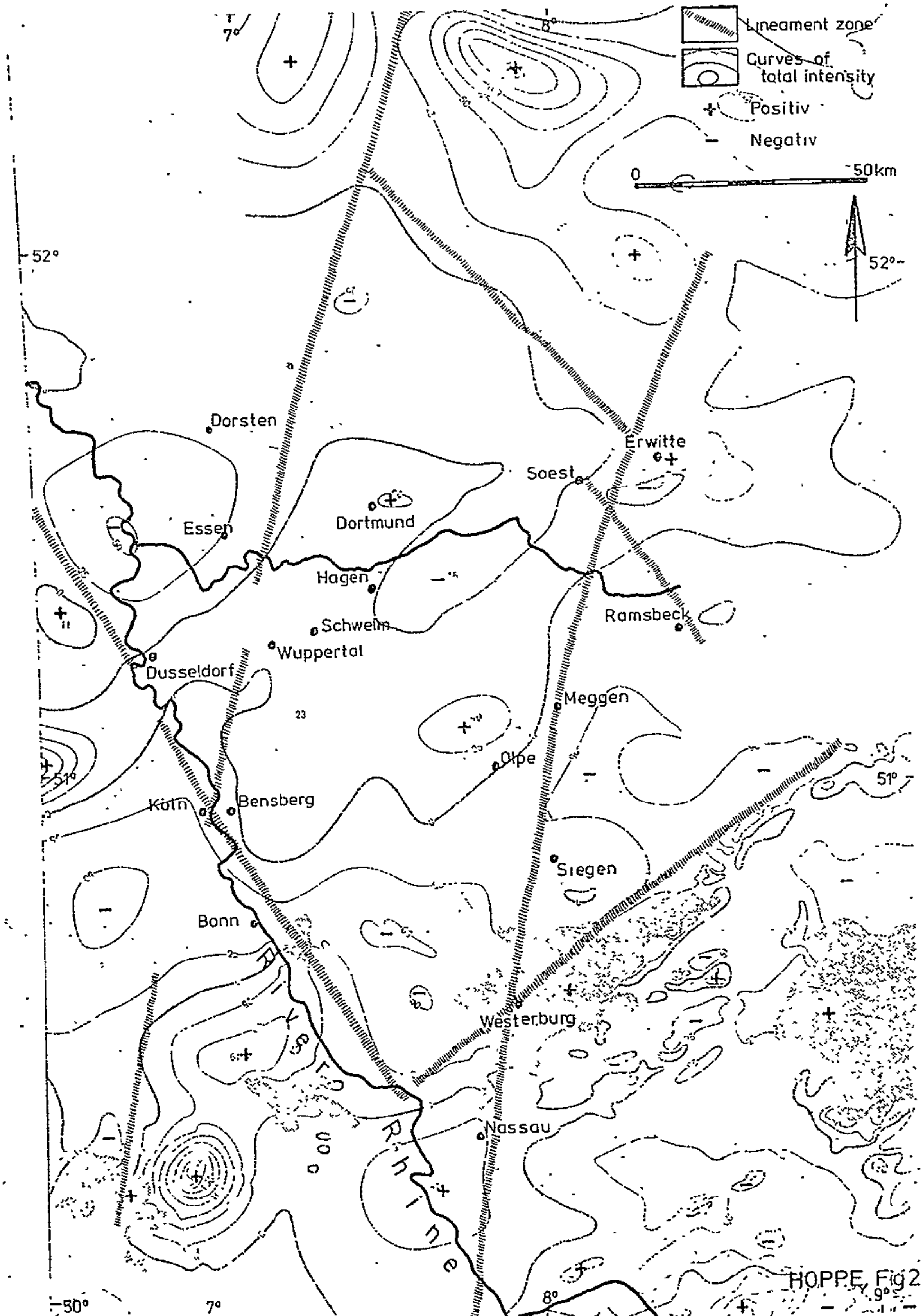
W. HANNAK (1964, Fig. 4) shows its Southern prolongation in the Nassau area with a zone of even bends in the fault axes. He deduces from this in Western Eruope a more or less regular division into parallel Rhenish underground structures situated about 40 Km apart (W. HANNAK, 1960, Plate 3).

2.1.3.4.4. Fault Lineament Tracery

Also A. PILGER (1957, Plate 8) assumes further, although not as strongly defined as the Siegen-Soest zone, deeply bedded structures in the Rhenish Massif both in the Renish and in other directions.

With the interpretation of ERTS-1 images it was possible to reveal at the surface these often only hypothetical lineaments, by means of mapping the photolineations in distinct fault zones and to trace them over greater distances. Take for example, the fault zones of the Siegen-Soest lineament that can be traced through the whole of the Rhenish Schiefergebirge and away across its border. In addition indications meriting a correction of some assumptions find: The displacement of the zone, coming from the South through Siegen, to the North of Meggen on the Unna-Giessen fracture (See A. PILGER, 1957, Plate 8) does not seem fully justified as the photolineations head directly North from there further in the direction of Erwitte.

Extract from the Aeromagnetic Map of the FRG



HOPPE, Fig 2

2-1-20a

If one follows this somewhat Eastwards from Soest situated zone of NNE-SSW directed faults from Erwitte through Siegen further towards SSW one encounters initially the Basalts of the Westerwald and secondly the Unterlahn-Lead/zinc district at Nassau.

The connection between ores of varying ages and types (Devonian Siderite, Carboniferous Lead/zinc ores, Paleozoic and Mesozoic Baryte) and volcanic rocks (Devonian Keratophyr, Carboniferous Diabase and Tertiary Basalt), strung in elongated fault-bundles supports the hypothesis of a Rhenish geo-fracture that has been active since its Precambrian initiation (see G. RICHTER-BERNBURG, 1974) up till the present time as a tectonic weak zone and path of ascent for Magma and the ore solutions derived from it.

The arrangement of the fault zones on the ERTS-1 interpretation (Plate 2) supports the suggestion that this geofracture is flanked by parallel faults (Compare W. HANNAK, 1960) and that similar deep reaching fractures exist elsewhere within the test area in identical or diverging directions (Compare A. PILGER, 1957). This assumption is further supported by the representation of the geomagnetic total intensity on the Aeromagnetic map of the FRG (D. EBERLE, 1973). The affiliation of the disturbing bodies in the Northern region (see fig. 2) suggests a Rhenish striking zone running from NNE between Dorsten and Dortmund, by-passing Essen to the East and then heading for Cologne. There it joins at an angle with a NNW-SSE striking series of disturbing bodies on the Lower Rhine that trends at the Middle Rhine to the SSE and at Koblenz ends on a broad cross-structure (Compare W. MEYER & Z. PERTHOLD, 1969).

A projection consisting of just these three lineaments superimposed onto the ERTS-1 interpretation (Table 1) already shows a close link to most of the gangue ore districts of the test area, particularly in the vicinity of the lineament cross-points. The ore veins generally lie in the direction of the lineaments or on fissures that feather off at an angle from the lineaments.

Also sedimentary deposits, such as the important occurence at Meggen (Lead/zinc, Pyrite, Baryte), fit into this arrangement and so indicate their connection with the great ore bearing lineaments. The distribution of the fault zones found with the aid of ERTS-1 imagery permits the assumption that further detailed studies will reveal a denser network of important fault zones.

2.1.3.5. Conclusions

2.1.3.5.1. Vein Deposits

With the assistance of ERTS-1 imagery an experiment was carried out to map fissures and faults of the Eastern part of the Rhenish Schiefergebirge, to co-relate their location with deep reaching old fractures and with ore mineralisation. It is assumed that such old, mainly North-South approximating lineaments may have been the path of ascent for Magma and ore solutions (See A. PILGER, 1957, G. RICHTER-BERNBURG, 1974, W. HANNAK, 1960, MOHR & A. PILGER, 1969).

2.1.3.5.2. Stratiform Deposits

Similar ascendance mechanism is assumed by W. KREBS (1973) for his interpretation of Genesis of stratiform Lead/zinc ore deposits in the Rhenish Massif but it is based on very different suppositions. The tectonic weak zones that assist the ascent of Magma and its derivatives he sees completely within the developement of the Variscian Geosyncline. He infers a mechanism of rising or falling SW-NE (Erzgebirgish) directed uplifts and troughs influenced by ascending Magma. The hinges of the uplifts created weak zones on which volcanic material and ore solutions could ascend. In addition there are often connected with these zones, rock formations such as reefs, conglomerates and Breccias.

2.1.3.5.3. Relationship between Faultbound and Stratabound Deposits

It can be assumed that in the Rhenish Massif a close genetic connection exists between veined and stratiform Lead/zinc deposits. The strong similarity in the ratio of different lead isotopes (J.S. BROWN, 1965, Fig. 3) speaks for a common origin of their hydrothermal ore solutions. Evidently these solutions after derivation from a Variscian magma chamber or after remobilisation of deep lying Mid-Paleozoic ore layers (J.S. BROWN, 1965) ascended to the same deep reaching faults. Over these production zones the ores settled in sediments, as impregnation and as metasomatic transformation and filled fissures that were opened in the rock.

2.1.3.5.4. Application of Results

The tectonic interpretation of the photolineations on ERTS-1 imagery of the Rhenish Schiefergebirge will be used by the German research group "Rhenoherzynikum" (Consortium of Government agencies, Universities and Industry) in their search for ore deposits in this region. Successful cooperation of this sort, between satellite imagery and ore prospection, has already been carried out in the French Central Massif (J.-Y. SCANVIC, 1974).

In the investigation presented here the main issue was to trace, in the greater part of the Rhenish Massif, the real regional connections between tectonic construction and the distribution of non-ferrous ore deposits, using as a base ERTS-1 imagery. This aim was achieved: with the assistance of ERTS-1 imagery a better picture of the region developed which traces more satisfactorily the situation of ore deposits than was hitherto possible with the existing geological maps.

However, although the results achieved give an initial general picture, detailed investigations, using technically improved references and further comparison with other programmes, will in the follow up, be necessary. In teamwork with ore-deposit specialists, the possibilities of their uses will have to be extracted from the results achieved so far and suggestions for the composition of a detailed geochemical and geophysical field survey will have to be worked out.

Bibliography

BROWN, J.S.: Oceanic lead isotopes and ore genesis. - Economic Geology, vol. 60, no. 1, p. 47-68, 3 fig., New Haven 1965.

DEUTLOFF, O.: Geological map of Nordrhein-Westfalen, scale 1 : 500 000. - Deutscher Planungsatlas, vol. Nordrhein-Westfalen, in print.

EBERLE, D.: Aeromagnetic map of the FRG, scale 1 : 1 000 000. - Hannover 1973.

HANNAK, W.: Untersuchungen über Raumbildung, Geochemie und lagerstättenprovinzielle Zusammenhänge auf den Blei-Zinkerzgängen der unteren Lahn in Abhängigkeit von der Groß- und Kleintektonik dieses Gebietes. Nunmehr erweitert auf den Raum Mittelrhein und Hunsrück. - DFG-Forschungsvorhaben 238/1+2, Final Report, 58 p., 15 fig., 4 pl., Clausthal-Zellerfeld 1960.

HANNAK, W.: Ergebnisse von Untersuchungen im Blei-Zink-Erzbezirk des südlichen Rheinischen Schiefergebirges. - Erzmetall, vol. 17, no. 6, p. 291-298, 9 fig., Stuttgart 1964.

KREBS, W. & WACHENDORF, H.: Proterozoic and Paleozoic Geosynclinal and Orogenic Evolution of Central Europe. - Geol. Soc. of America Bull., vol. 84, no. 8, p. 2611-2630, 4 fig., Boulder/Colorado 1973.

MEYER, W. & PERTOLD, Z.: Strukturkartierung in ungegliederten Gesteinsfolgen. - Clausth. Tekt. Hefte, vol 9, p. 249-255, 3 fig., Clausthal-Zellerfeld 1969.

MOHR, K. & PILGER, A.: Zum Begriff Lineament. - Clausth. Tekt. Hefte, vol. 9, p. 7-18, Clausthal-Zellerfeld 1969.

PAPROTH, E. & WOLF, M.: Zur paläogeographischen Deutung der Inkohlung im Devon und Karbon des nördlichen Rheinischen Schiefergebirges. - N. Jahrbuch Geol. Paläont., Mh., y. 1973, no. 8, p. 469-493, 12 fig., 1 pl., Stuttgart 1973.

PILGER, A.: Über den Untergrund des Rheinischen Schiefergebirges und Ruhrgebietes. - Geol. Rundschau, vol. 46, p. 197-212, 3 fig., 1 pl., Stuttgart 1957.

STENGEL-RUTKOWSKI, W.: Bruch- und Dehnungstektonik im östlichen Rheinischen Schiefergebirge als Auswirkung des Oberrheingrabens. - Zeitschr. deutsch. geol. Ges., vol. 121, p. 129-141, 3 fig., Hannover 1970.

RICHTER-BERNBURG, G.: The Oberrhein Graben in its European and Global Setting. - Approaches to Taphrogenesis, Inter-Union Comm. on Geodynamics, Sc. Report no. 8, p. 13-43, 11 fig., Stuttgart 1974.

SCANVIC, J.-Y.: Structural investigations in the Massif Central-France. - Report BRGM, Serv. Géol. Nat., SR 003-1, 17 p., 1 fig., Orléans 1974.

STORK, G.-H., BACHMANN, M., HOYER, P., QUITZOW, H.W. & STADLER, G.: Lagerstättenkarte II (Kohlen, Erdöl und -Gas, Salze, Erze und Minerale), scale 1 : 500 000. - Deutscher Planungsatlas, vol. Nordrhein-Westfalen, Bonn-Bad Godesberg 1973.

WOLFF, W.: Geophysikalische Beiträge zur Erforschung des tieferen Untergrundes des Rheinischen Gebirges. - Geol. Rundschau, vol. 46, p. 186-196, 5 fig., Stuttgart 1957.

2.1.4. Results of an ERTS-1 Image Analysis of the Alps by J. BODECHTEL and B. LAMMERER - Center for Geo-Photogrammetry and Remote Sensing - München

Abstract:
In spite of the manifold geological works in this area the application of ERTS data revealed yet unknown or partly unknown structural systems within the Alps.
Strike-slip-faults to the main fold axis could be delineated over long distances, although they are partly camouflaged by young series. The knowledge of the main structure systems could be supplemented.

For the evaluation of the Alpine area the following geological and tectonic results were obtained:

2.1.4.1. Conformation of formerly evaluated data
Recent work on ERTS data in the molasse foreland of the Alps confirms the idea of young or actual compression of the molasse in a N-S direction, producing large and young shear fracture systems.

The results were also substantiated by other authors using different methods. LEMCKE (1973) showed the existance of a pliocene or post pliocene E-W trending trough in the Bavarian molasse by evaluation of oil well drilling data. Furthermore, the existance of actual tectonic stress is shown by an over-pressure in the pore water in drillings. Lastly, actual tectonic is shown by precise nivellement measurements in the Austrian Central Alps (SENFTEL, 1973).

2.1.4.2. Influence of Sun angle for Lineament evaluation
Due to the high relief of the alpine mountain region the direction of sun angle effects the interpretation sketch.

High sun elevation is most useful for detailed work, especially for stereoscopic viewing. The region is equally illuminated. Low sun angle gives a very plastic relief which emphasises main lineament structures but details may be lost by different illumination of slopes.

Lineament structures with the same azimuth as the sun are almost impossible to see in a monoscopic view (in mountain regions).
(Compare interpretation sketches of the region around Innsbruck at different seasons - Fig. 1a,b). A strong lineament system striking about 130° could not be detected on the summer image, when the sun azimuth was 138°, but is clearly seen on the winter image with a sun azimuth of 157°.

Ideal conditions are given at the parts of stereoscopic overlap, structural features can be localized more precisely and their nature can be more easily identified.

For a geologic interpretation of mountain regions a high sun elevation and stereoscopic overlap would be most effective.

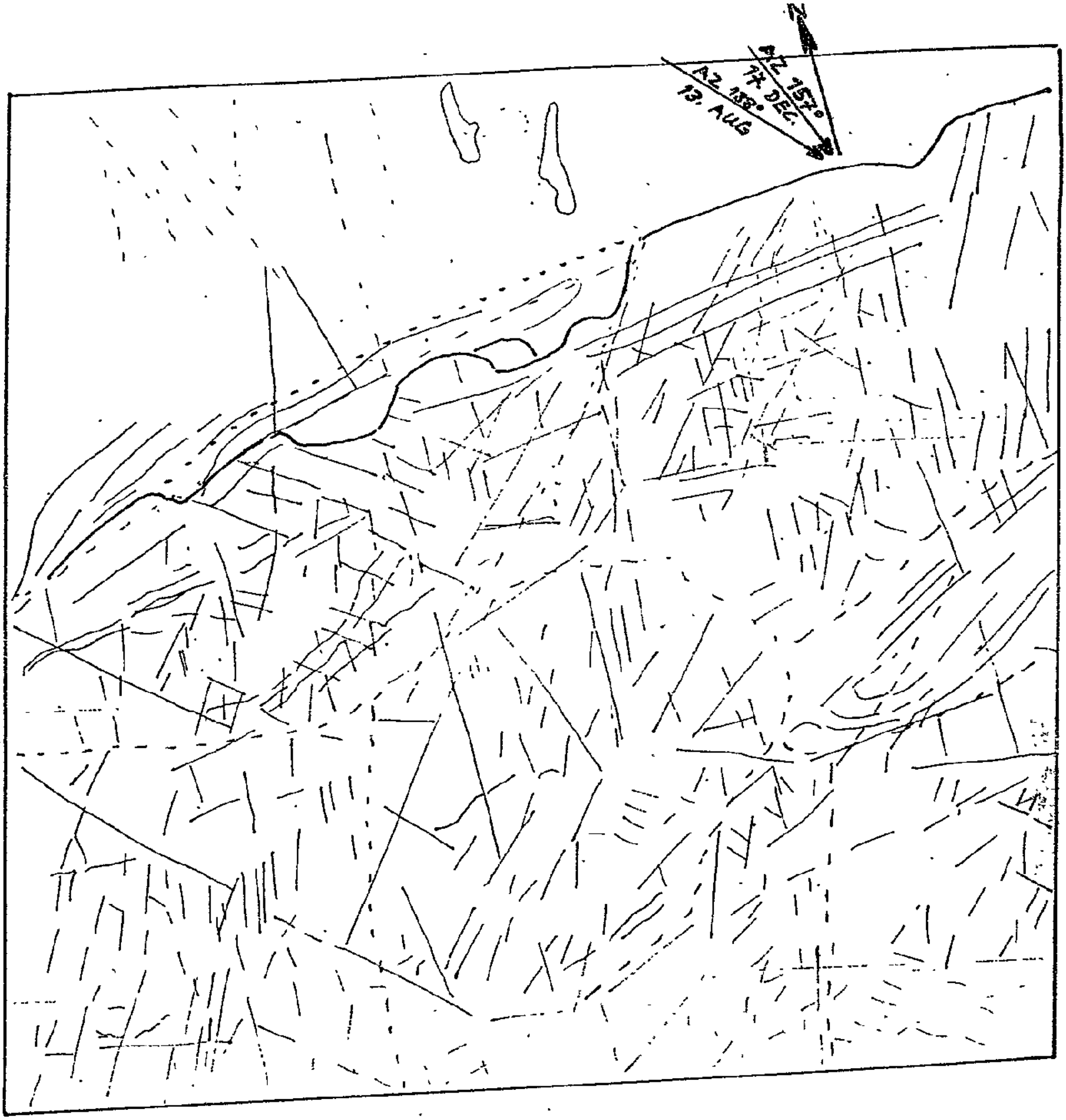
2.1.4.3.

In the region of the Swiss Jura and the Lac leman outcrops of bedding planes have been traced which show a characteristic pattern of interfering main directions. They may show a change in direction of tectonic stress (Fig. 2a, b).

2.1.4.4. Lineament-map of the Western part of the Alps

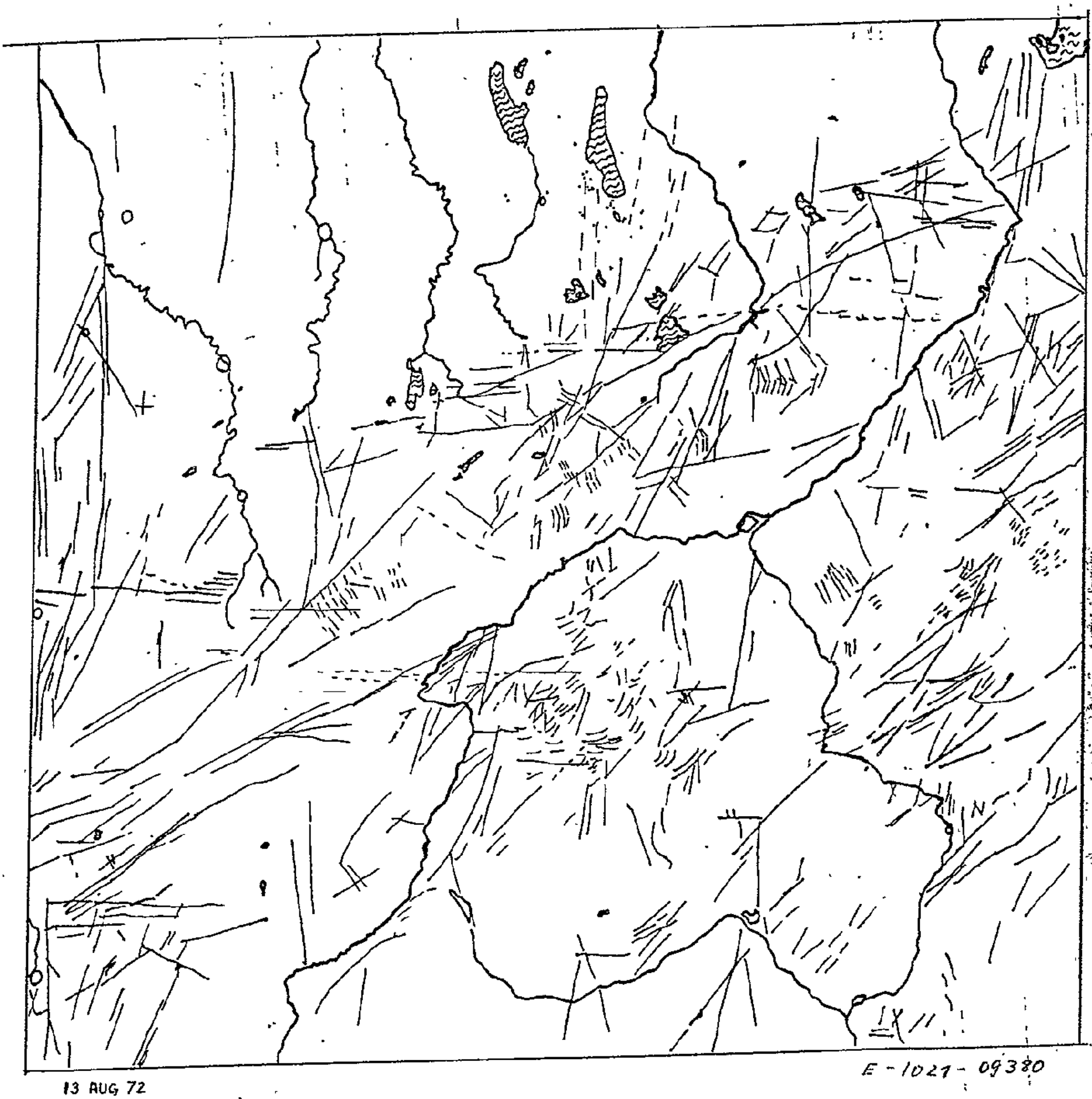
The map enclosed is based on images of different quality and different sun angle, cloud cover etc., so that not all parts are of equal quality (Fig. 3).

A lot of far reaching lineaments can be detected, teconically homogene realms can be seperated from those adjacent, which are different; but for an interpretation one needs to collect a lot of ground data which are widely scattered.



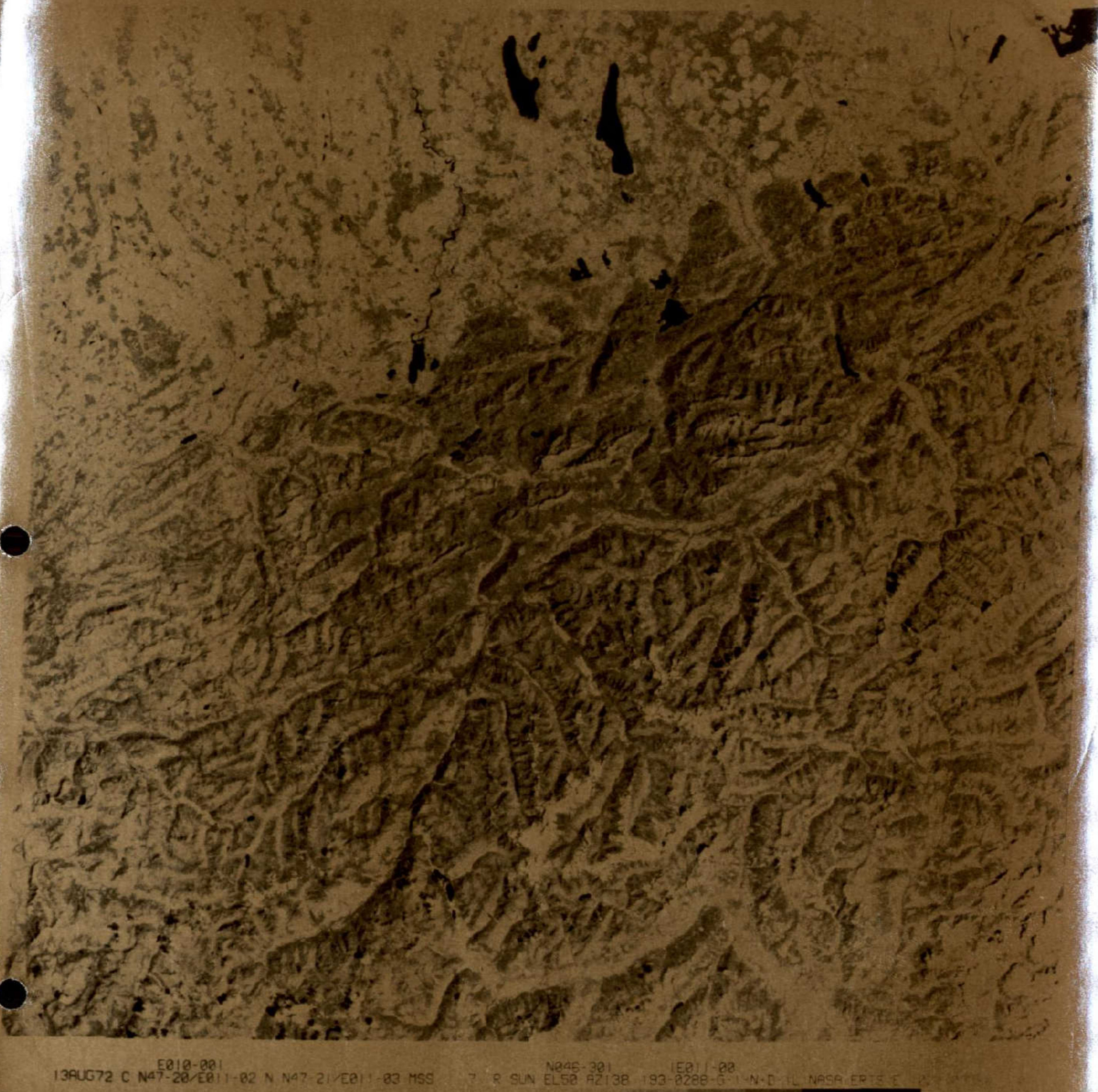
J. BODECHTEL & B. LAMMERER Fig. 1a: Structural analysis of a part of the Central Alps South of Munich as derived from ERTS-1 image 1147-09385-7 taken on 17 Dec. 1972. In the left center part of the image lineations with an azimuth of 130° are visible which do not show up in Fig. 1b.

2-1-27a



J. BODECHTEL & B. LAMMERER Fig. 1b: Structural Analysis of a part of the Central Alps South of Munich as derived from ERTS-1 image 1021-09380-7 taken on 13 Aug. 1972.

2-1-27B



J. BODECHTEL & B. LAMMERER Fig. 1c: ERTS 1 scene 1021-09380-7 taken on 13 Aug. 1972. At center top Lake Ammer and Lake Starnberg immediately South of Munich. At the bottom the Eisack-valley with the towns of Merano and Bolzano in Italy.

2-127C

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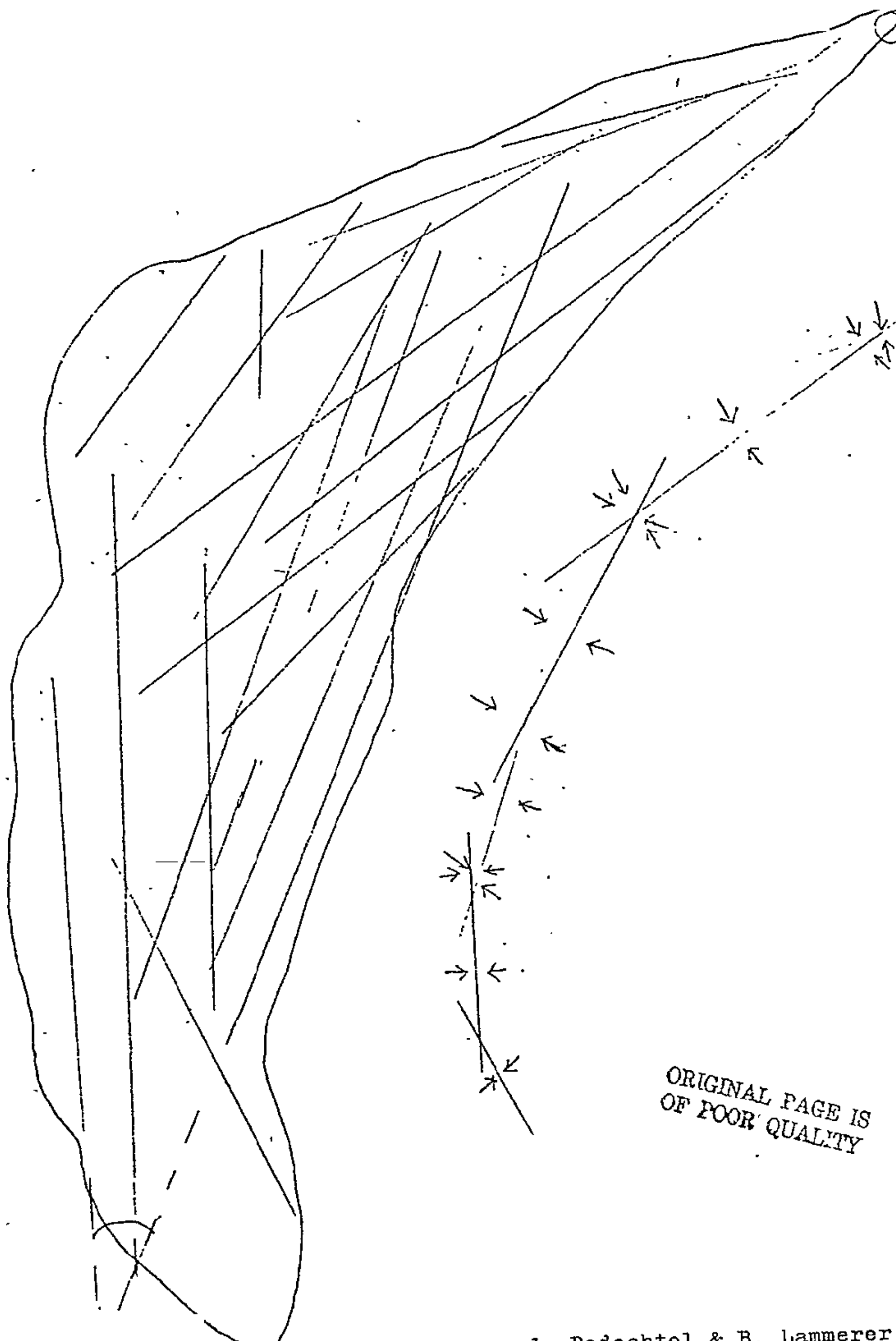
J. BODECHTEL & B. LAMMERER Fig. 2a: Bedding planes of the Western Alps as seen on ERTS-1 images 1060-09552-7 and 1060-09554-7

2-1-27d



J. Bodechtel & B. Lammerer Fig. 2 b
Direction of tectonical stress
in the western Alps and forelands
as derived from fig. 2a

2-1-27ε 21

Therefore the interpretation will take more time and is not presented here.

2.1.4.5.

An attempt was made to interpret a photographically enlarged ERTS-image (scale 1 : 200 000) of the Bavarian molasse.

Compared with geologic ground truth, there is a remarkable coincidence, but ERTS-images reveal a lot of hitherto unknown structures (especially in the Northern part). They look like traces of bedding planes, camouflaged by more or less thin alluvial and diluvial sediments. It will take some time to clear this problem. In the interpretation map mainly bedding planes are shown forming in part synclines together with glacial moraines and the track of ice flow and major lineaments (Fig. 4).

The evaluation techniques are primarily based on conventional photointerpretation techniques. With reference to multispectral data the possibilities of conventional interpretation are very restricted. By optical comparison only up to 3 bands can be visually combined.

2.2. Coastal studies

One of the main potential applications for repetitive space observations is the monitoring of dynamic processes such as earth quakes, flood hazards, air pollution and morphological changes in coastal and tidal areas. The original intention, was to evaluate the conditions of sand migration off the German coast using repetitive ERTS-1 coverage.

Unfortunately, due to heavy cloud cover, the ERTS-1 imagery is limited to two overpasses, one covering a 125 km sector of the coast in the border area of Southern Denmark and Northern Germany, the other, a 100 km sector of the coast in the area of the Elbe Estuary.

Even with this limited material it was still possible to demonstrate that a systematic observation of the coastal areas by ERTS or similar satellites will increase the reliability of nautical charts considerably and would allow a more economic ground survey by research vessels.

2.2.1. Topography of the tidal flats off the Western coast of Southern Denmark and Northern Germany by P. HOPPE - Federal Geological Survey - Hannover

2.2.1.1. Scope of Research

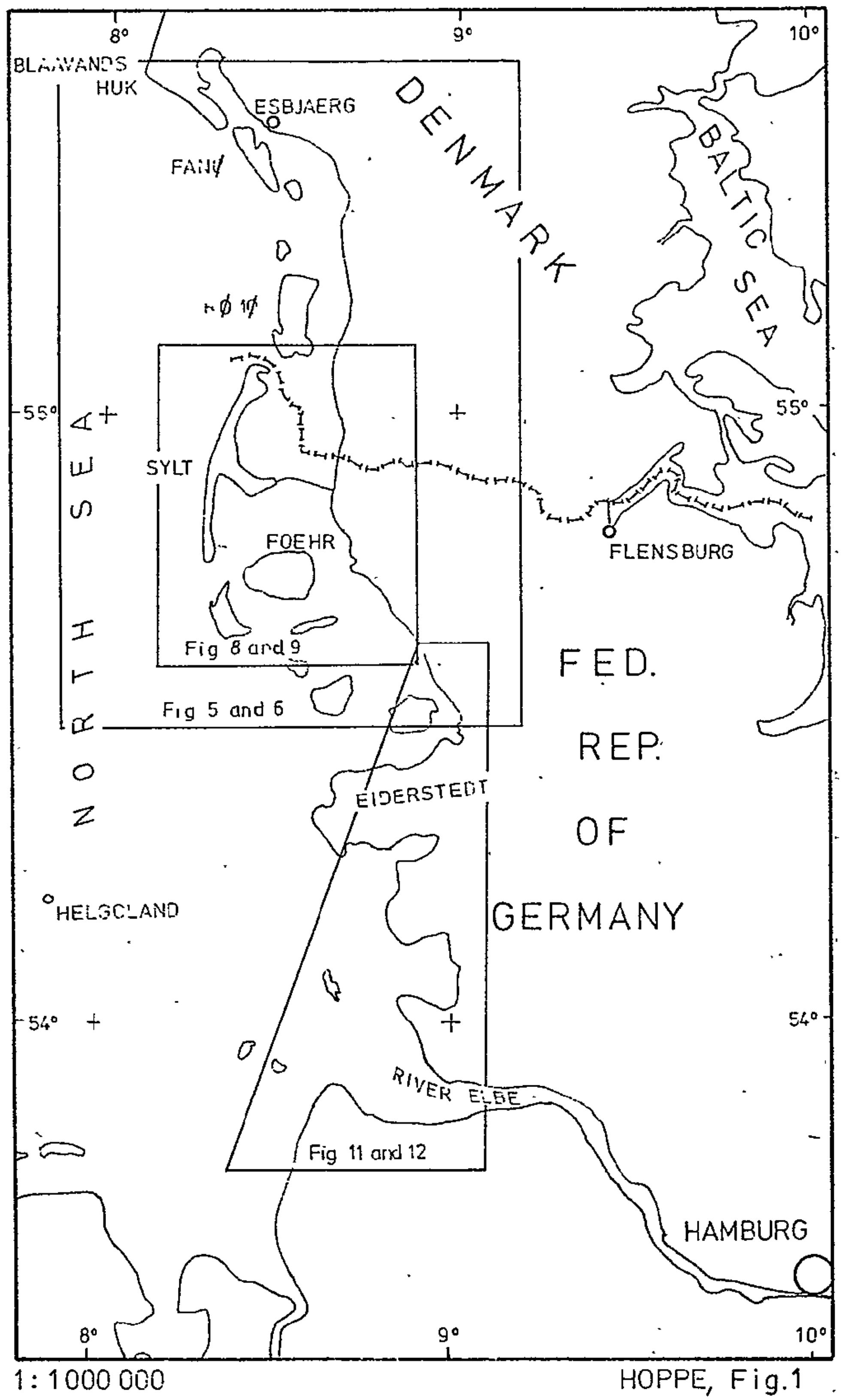
NASA ERTS E - 1043 - 09583 (Southern Denmark)
1043 - 09590 (Northern Germany, Schleswig-Holstein)
1078 - 09532 (Northern Germany, Schleswig-Holstein and Lower Saxony)
1078 - 09535 (Northern Germany, Lower Saxony)

Originally it was intended with the aid of ERTS imagery, to carry out a study of sediment movement in the tidal flats off the German North Sea coast. Unfortunately the photo cover is incomplete because large areas, for example the Ost Friesian Islands, are situated under cloud cover. The area of the German Bight and the North Friesian Islands (see Fig. 1) are shown in single points cover. A 100 kilometer sector of the coast, including the North Friesian Islands, shown by the two scene strip 1043 - 09583 / 09590 dated 4 Sept. 1972 was taken at about high tide (Fig. 2). A 125 kilometer sector of the German Bight embracing an area from the Eiderstedt Peninsular to the immediate vicinity of the Weser estuary is covered by a two scene strip, 1078 - 09532/09535 taken on 9 Oct. 72, 1 - 2 hours after low tide (Fig. 3).

2.2.1.2. Initial Preparation

2.2.1.2.1. Manual Photo Interpretation

This material is inadequate for carrying out the originally intended experiments. It suffices only for topographical interpretation of the tidal flats when above and below water level which can be compared with the topography presented by recent German sea charts and other, in some cases older, publications and records to establish superficial changes in the tidal flats.



Index map of the investigated area

2-2-2a

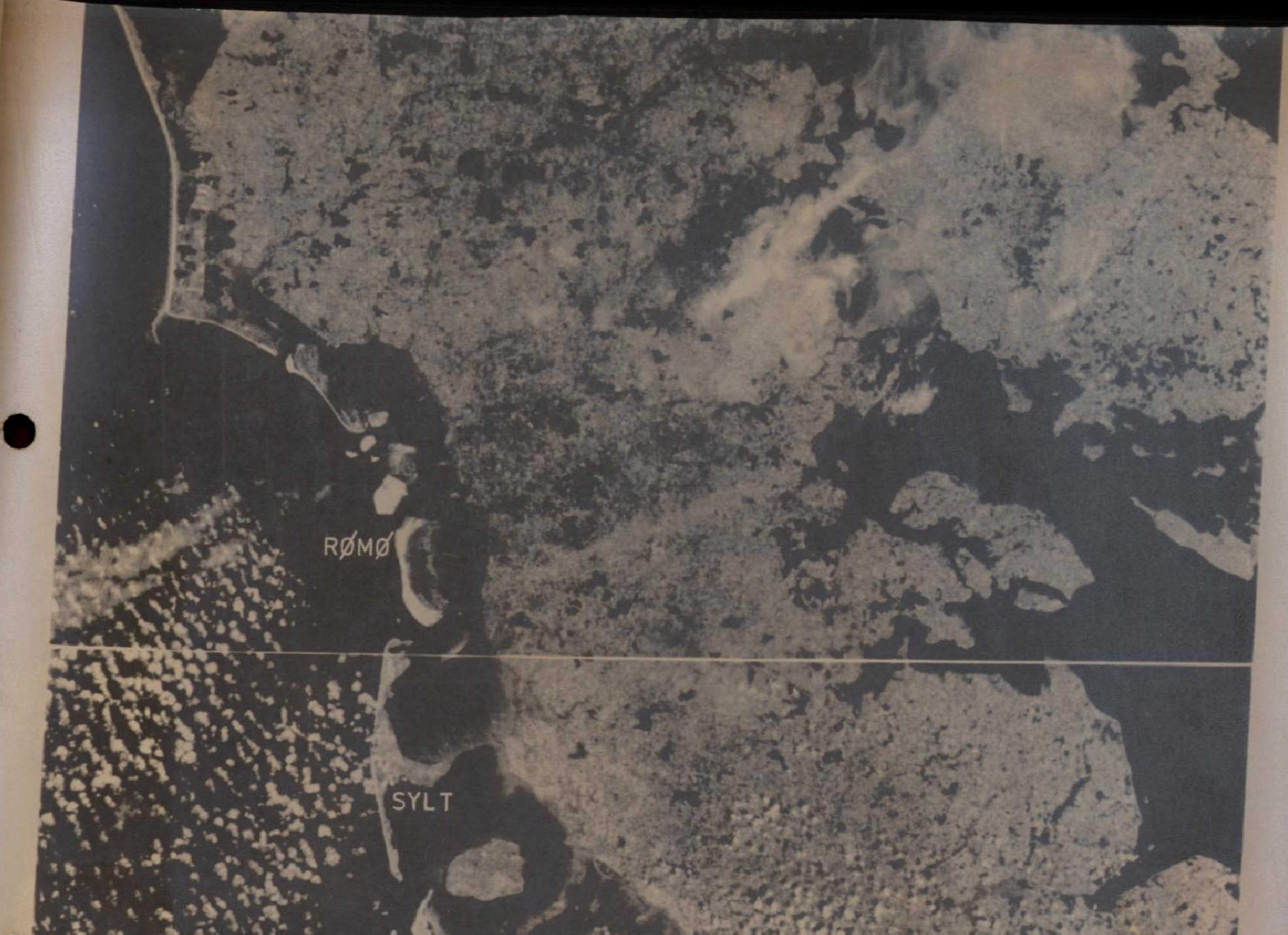


Fig. 2

Research area North of the Eiderstedt Peninsular. Mosaic of ERTS-1 images 1043 - 09583 and 1043 - 09590, MSS channel 5.

Scale 1 : 1.000.000 9-2-2B

Fig. 3

C.2

Research area South of the Eiderstedt Peninsular. Mosaic of ERTS-1 images 1078 - 09532 and 1078 - 095 35, MSS channel 7.

Scale 1 : 1.000.000 2-2-2c

In this way, for the two areas North and South of the Eiderstedt Peninsular, the outline of the coast and the morphology of the tidal area were extracted from ERTS imagery using the capabilities of multi-spectral scanning: in MSS channels 6 and 7 (Red and near Infrared) there was no apparent water penetration. As a result areas of water were shown in the same even dark tone in direct contrast to areas of land, the coastline was most prominent. The MSS channels 4 and 5 (Green and Orange) show the structure of the sea bed under shallow water as the degree of penetration is greater when the waves are shorter.

These capabilities permitted the interpretation of the shallow water areas on the imagery North of the Eiderstedt Peninsular, in spite of high tide.

2.2.1.2.2. <u>Computer Directed Interpretation using Colour Equidensity</u>

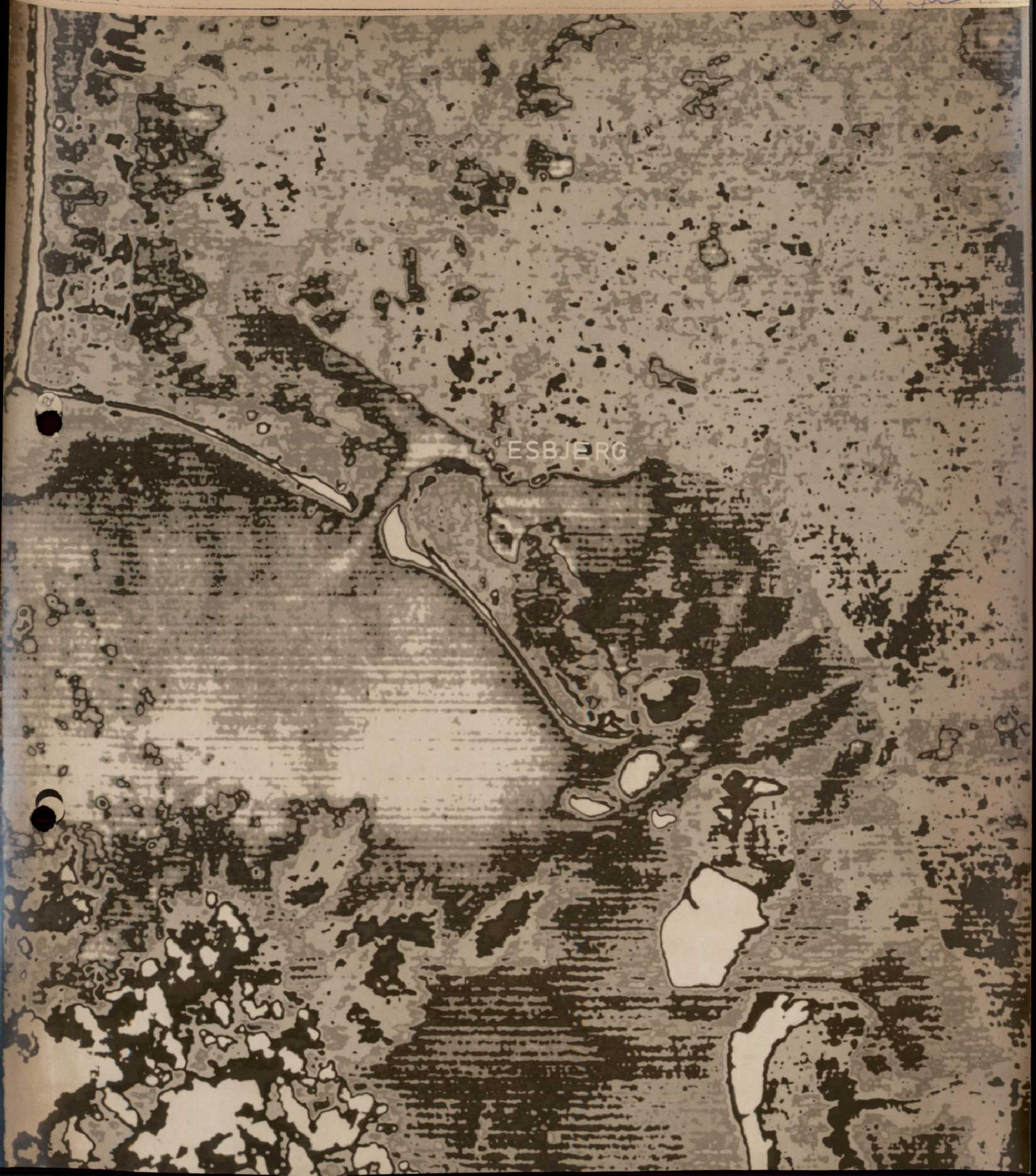
On a trial basis, H.S. HELBIG, DFVLR Oberpfaffenhofen prepared last year for the Northern test area two colour equidensity maps, one with a scale of 1 : 250 000 covering the Western coast of Southern Denmark (Part of ERTS E 1043 - 09583, shown in Fig. 4 in black and white), the other scale 1 : 1 000 000 a copy of image ERTS E 1043 - 09590. The interpretation of enlargements to 1 : 250 000 prepared by computer and divided into twelve colour stages is scheduled to take place during the coming summer.

In principle colour equidensity would be more suitable for the morphological sub-division of the visible sea bottom whereby the differing grey tones of satellite imagery would be translated into depth levels. However grey tone deviations, due to changes in light reflection on the sea bed - induced by changes in vegetation or the size of sediment particles, are not taken into consideration. Apart from this, technically induced colour alterations increase as the scanner lines are enlarged or as they appear as changes in the grey tone strengths one image to the other, they greatly affect the separation of the individual depth levels.

Fig. 4

Copy of colour density sliced ERTS-1 image 1043 - 09583, showing the sector from Esbjaerg to Rømø, scale 1 : 250.000.

2-2-3a



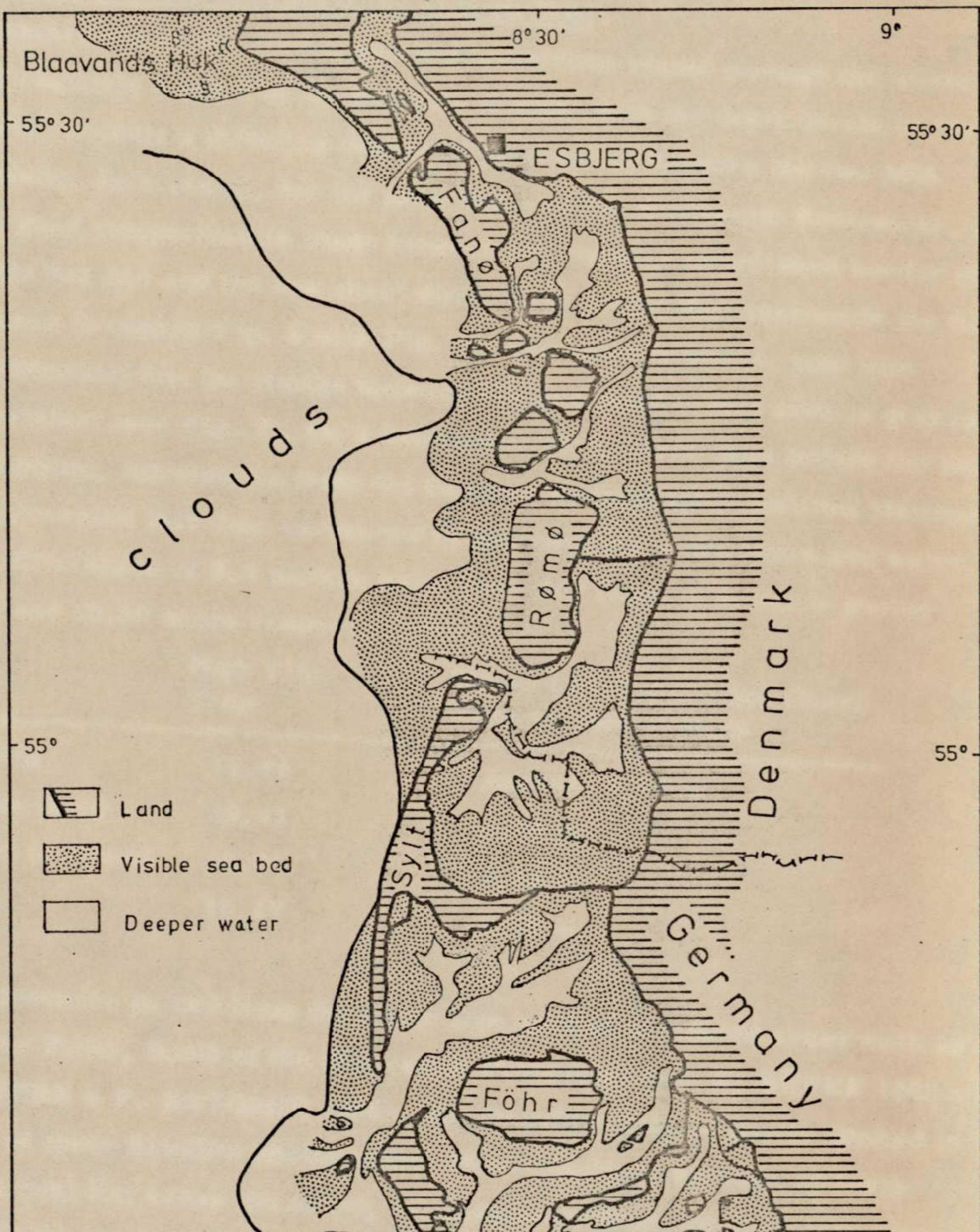
2.2.1.3. Scientific Deductions

2.2.1.3.1. Photo Interpretation at High Tide

A comparison of the visible sea bed borderline shown through the water in MSS channels 4 and 5 of the Satellite photos, with the depth levels of the sea charts, reveals a differing degree of penetration between the two MSS channels. As a result, for the area North of the Eiderstedt Peninsular, a very good comparison is made between the visually established border of the visible sea bed and the sea chart water level (zero) that surrounds the tidal flat area (compare Fig. 5 with Fig. 6). One must however, take into consideration that the change between ebb and flood in this area is generally inconsistant (see Fig. 7). On 4 September 1972, three days before the new moon phase, information from the German Hydrographic Institute Hamburg (DHI) revealed that time variations of approximately two hours and water level differences of 2.3 meters were recorded (time of Satellite photos 10.58 and 10.59 hours respectively):

Place	High Tide Time	Water Level above Sea Chart Zero at time of photo
Esbjaerg	12.09	approx. 1.10 m
Hörnum (Sylt)	10.43	1.92 m
Wittdün (Amrum)	10.03	2.42 m
Husum	10.47	3.40 m

The experience gained from the water line method in limited areas such as the Outer Eider, South of the Eiderstedt Peninsular (see N. RÜPKE 1966 and J. SINDERN & F. KATHAGE 1966), can therefore only be partly applied in the use of these Satellite photographs. Particularly in the case of lowly inclined tidal flat areas the relief, reconstructed from the grey tone stages, cannot be drawn directly to sea chart zero as due to time and water level differences these stage contours do not represent true depth levels. Proportionally smaller areas would yield better results.

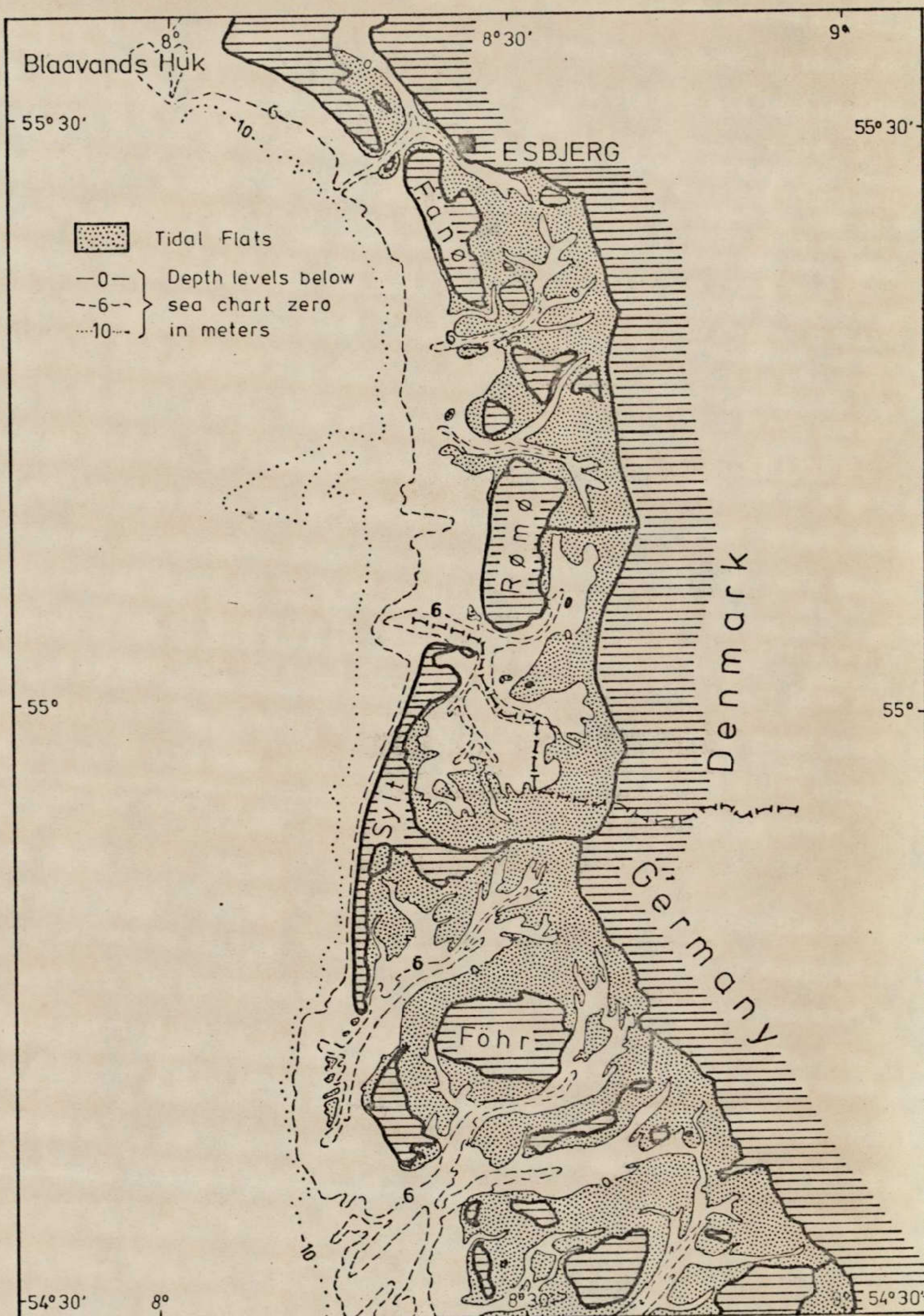


1: 500 000

Fig. 5

Borderline pattern of the visible sea bed in area North of the Elderstedt, reconstructed from ERTS - images. No. 1043 - 09583 and 1043 - 09590, taken on 4th September 1972

2-2-4a



1:500 000

Fig. 6

Sketch map of the water depth levels in shallow water area North of the Eiderstedt Peninsula, drawn from sea chart no. 50.

2-2-4 B

In Figures 8 and 9 at a scale of 1 : 250 000 a section of this area covering the tidal flats between Southern Rømø and Pellworm is shown in more detail. The Satellite sketch Fig. 8 shows the edges of the visible sea bed in MSS channels 4 and 5, the sea chart sketch Fig. 9 the depth levels for 0, 2, 6, and 10 meters. A comparison of both figures reveals a marked similarity between the visible edge in channel 5 and the tidal flat border (sea chart zero), the edge in channel 4 and the two meter level. From these facts and the measured water levels (Hörnum, Wittdün, Husum) one can derive a water penetration of 2 to 3 meters in channel 5 and of 4 to 5 meters in channel 4. The degree of water penetration achieved coincides with data from mainly 5 meters or less on the North Sea coast published by H.G. GIERLOFF-EMDEN 1961.

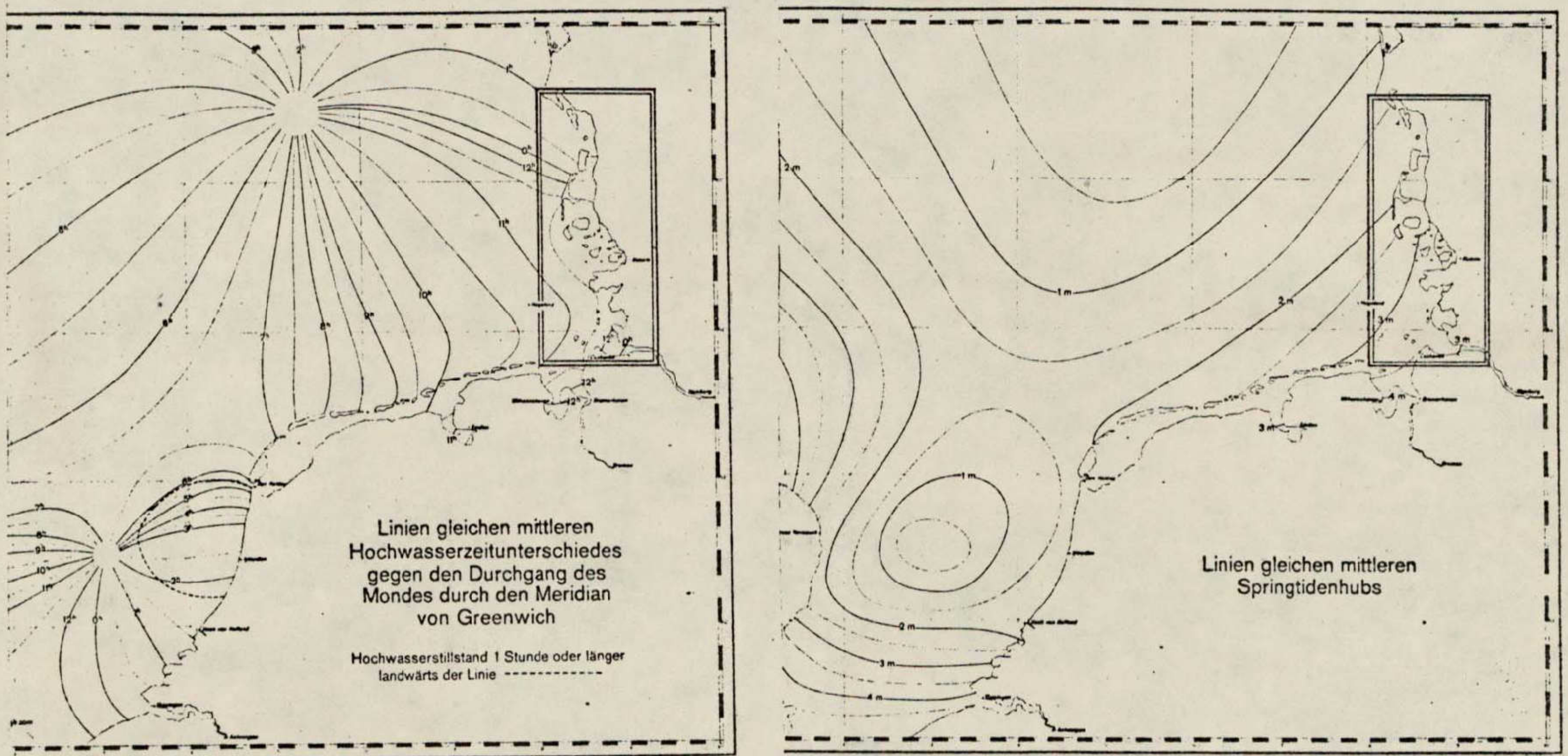
In Fig. 10 this area can be seen as an air photo mosaic. It was flown by Messrs N. RÜPKE of Hamburg in 1958 at low tide. The water free area in this photo is larger than the tidal flat area shown in the sea chart (see Fig. 9). The similarity with the channel 4 interpretation (see Fig. 8) is most marked although one must take into consideration that in the visual satellite image interpretation the more minor water runlets have been neglected.

As there were no ERTS photo sequences available it was not possible to tell whether lighter areas shining through the water were sea bed or suspended sediment such as can be found West of Sylt and Rømø. Adequate research was successfully carried out by V. KLEMAS in 1973 for the Delaware Bay/USA, using four different ERTS images.

<u>2.2.1.3.2. Photo Interpretation at Low Tide</u>

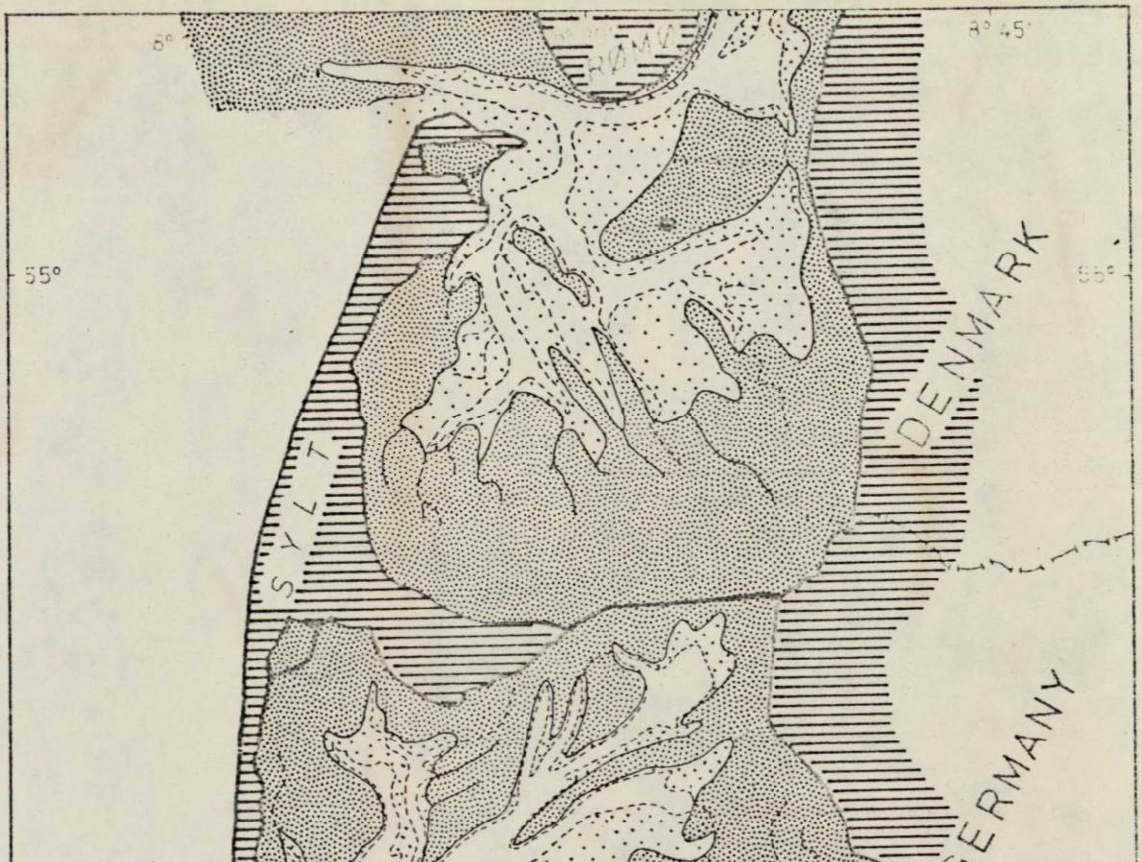
The area between the Eiderstedt Peninsular and the Elbe Estuary is covered by a two photo sequence which was taken on the 9 October 1972 about two hours after low tide (ERTS E 1078 - 09532/09535, Fig. 3). This area proved to be more suitable than the Northern research area as the calculated tidal time differences were almost 1 hour and the water level differences were less than 1 meter. Unfortunately MSS channels 4 and 5 were not

2.2.5.2



HOPPE ,Fig. 7

Map showing annual mean high tide time differences (left side) and spring high tide levels (right side) in the Southeastern North Sea. Extracted from Gezeitentafeln 1972, vol.I. Area of investigation is enclosed by double lines.

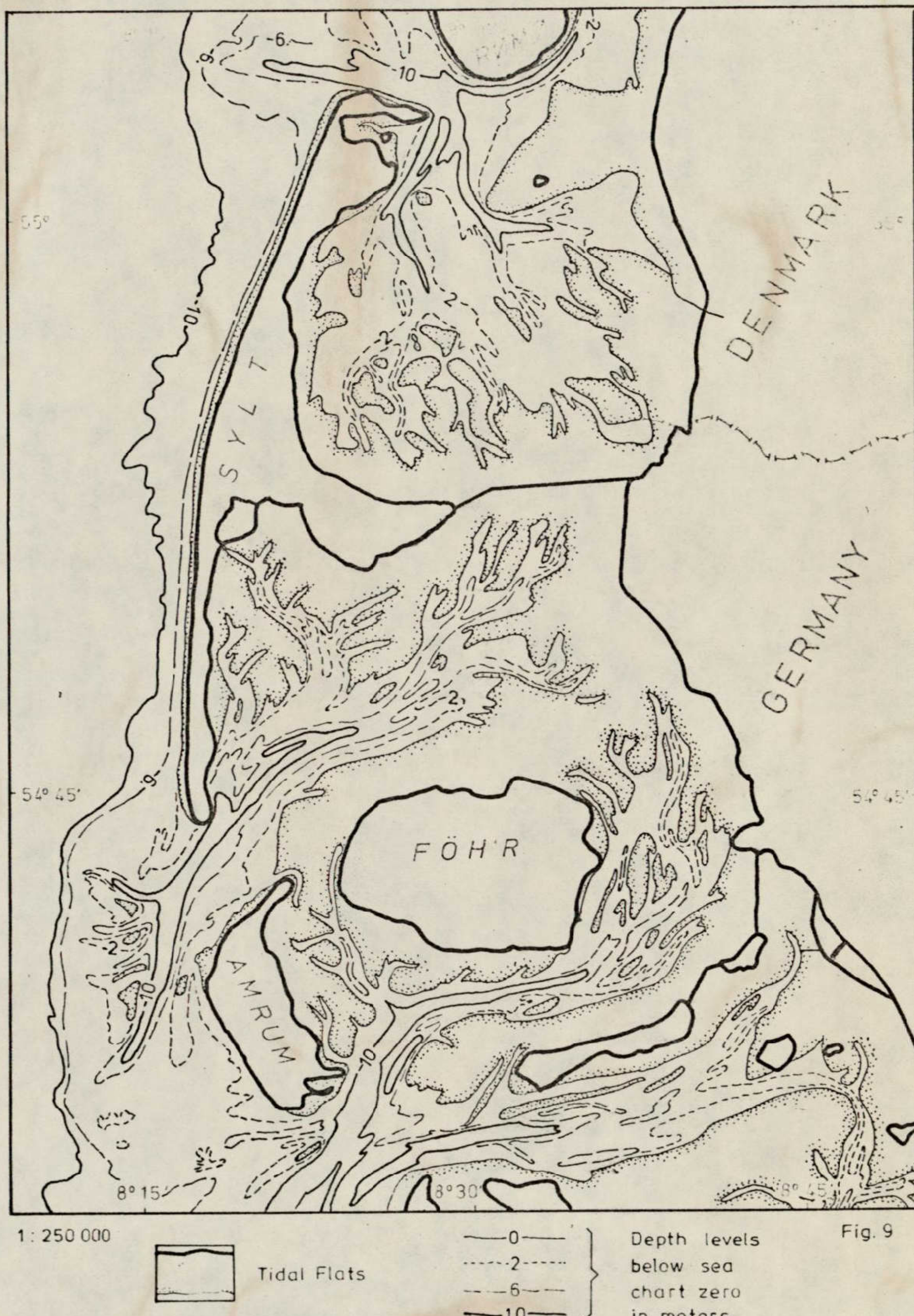


1:250000

Visible sea bed : Channels 4 and 5 Only channel 4

Fig. 8

The tidal flats on the Danish-German border between Rømø and Pellworm, transferred from ERTS-1 image 1043 - 09590.



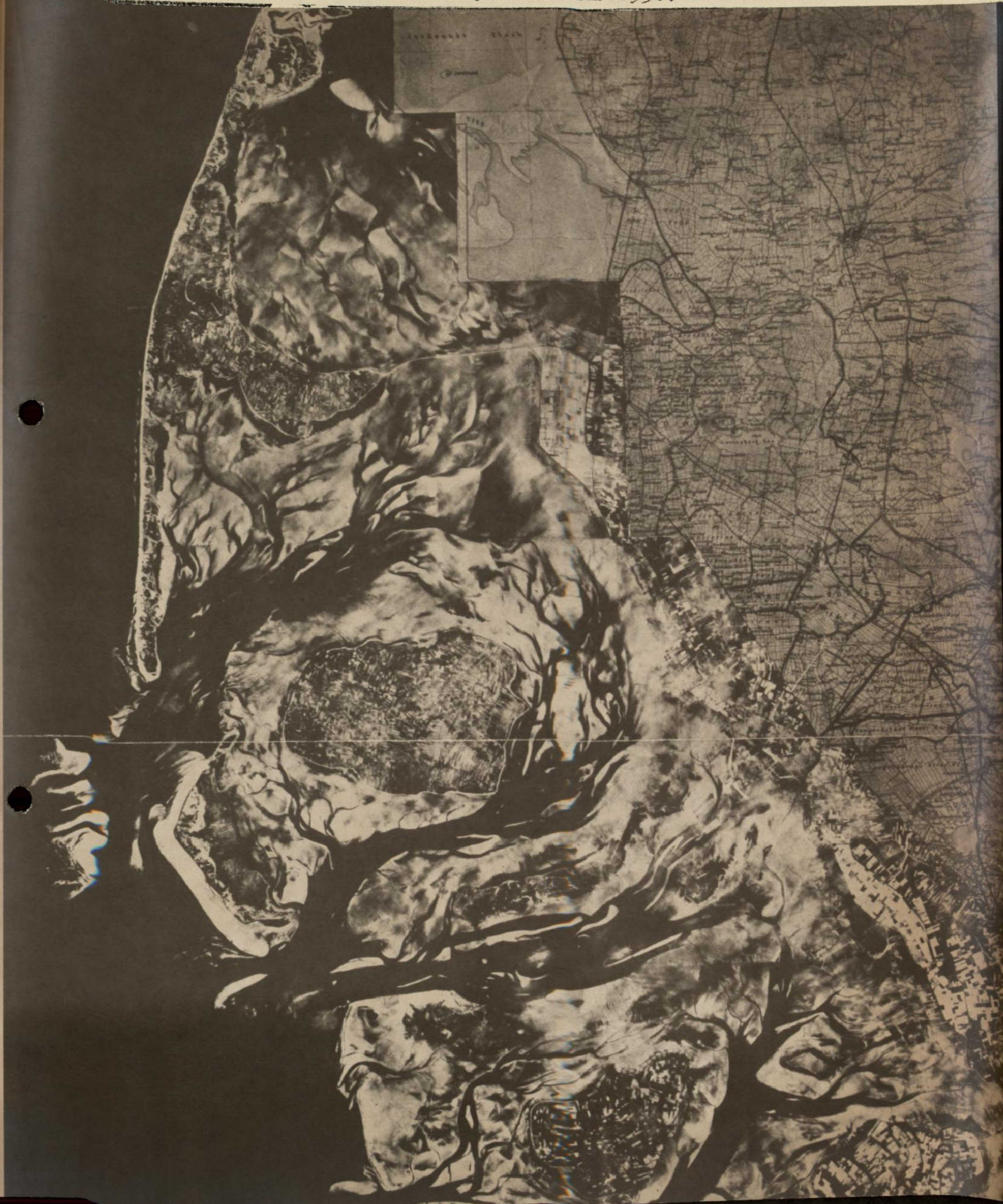
Tidal region at the Danish-German border extracted from German sea chart nos. 107 and 108 (1970, scale 1:50.000).

2-2-5c

2-2-5 8t

Fig. 10

The German North Sea coast from Sylt to Pellworm at low tide.
Northern part of the air photo mosaic, scale appr. 1 : 250.000,
taken by N. RÜPKE 1958.



suitable for interpretation purposes due to heavy haze and clouds so that only the water line in channel 7 could be evaluated despite the fact that at 10.35 hours, the time of exposure, the water was already rising:

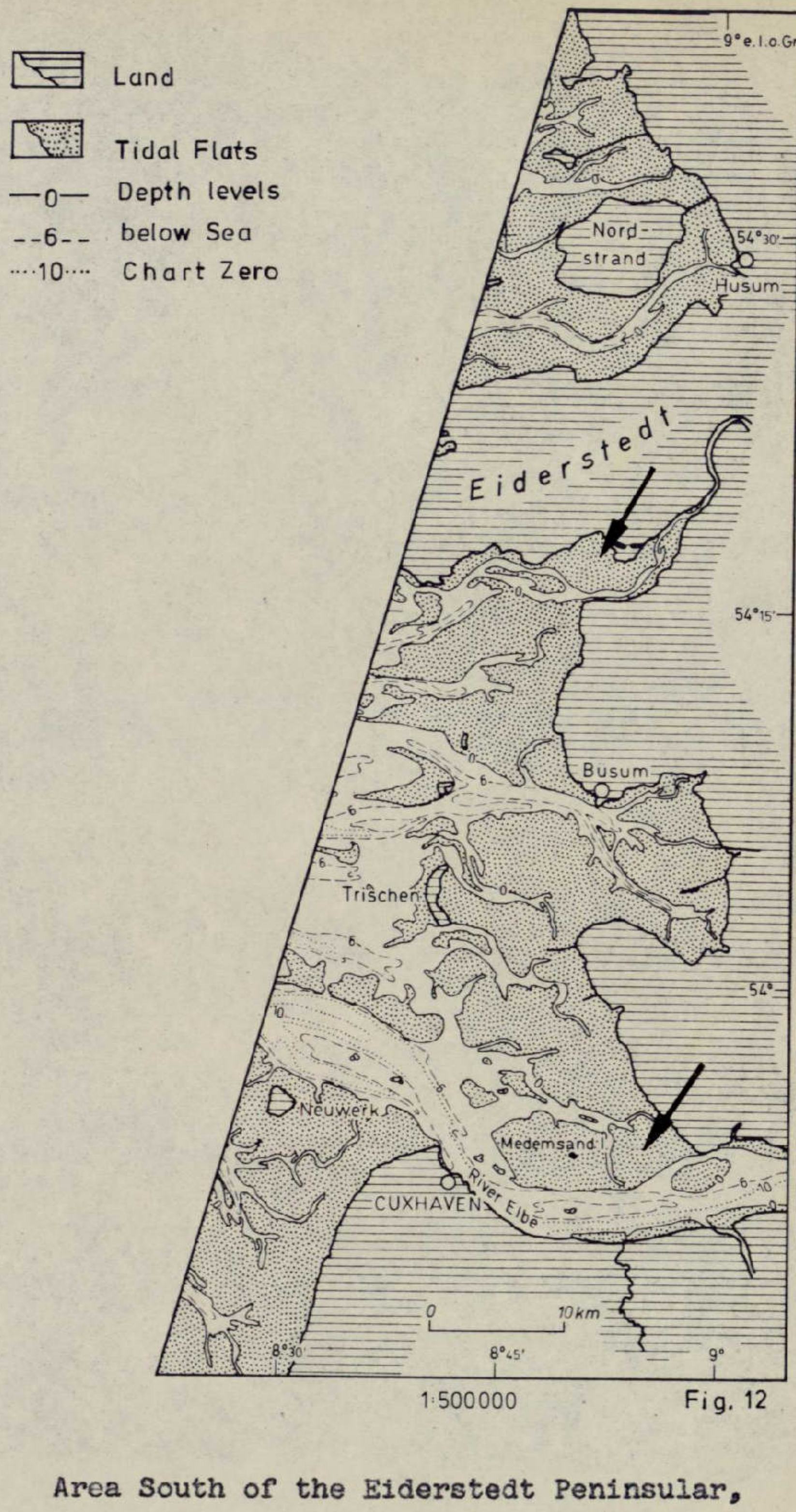
Place	Low Tide Time	Water Level above Sea Chart Zero at 10.53 hours
Cuxhaven	08.50	1.60 m
Büsum	08.02	2.27 m
Husum	09.30	1.27 m

Where in connection with erosion the tidal flats present a low relief form as can be seen between Neuwerk and Cuxhaven (see report by H. GÖHREN, 1970) then the greater part is already flooded at an early stage in the flood tide (compare with Figs. 11 and 12).

In direct contrast to this the Medemsand, East of Cuxhaven, a tidal flat spit with steeply shelving sides, is still relatively clear of water. The illustration in Fig. 12 (extracted from Sea Chart No. 50, dated 1969) shows a large North-South runlet that cuts through the Medemsand, it is only visible in the North on the Satellite photograph. The more recent Sea Chart, No. 49 (dated 1972, large scale 1 : 1 000 000), confirms that the runlet has sanded up in recent years.

In addition the map section (A.W. LANG, 1970) reproduced in Fig. 13 shows what radical changes have occurred in the Elbe Estuary.

This example shows the particular value of general air photographs that will be available shortly and at frequent intervals. As the correction of sea charts, due to high costs and demands on time can only be carried out for smaller areas and as a result, despite the effort involved, a universal representation of tidal flat morphology cannot be achieved.



1:500000 Fig. 12

Area South of the Eiderstedt Peninsular, taken from sea chart no. 50, 1969.

2.2.6a

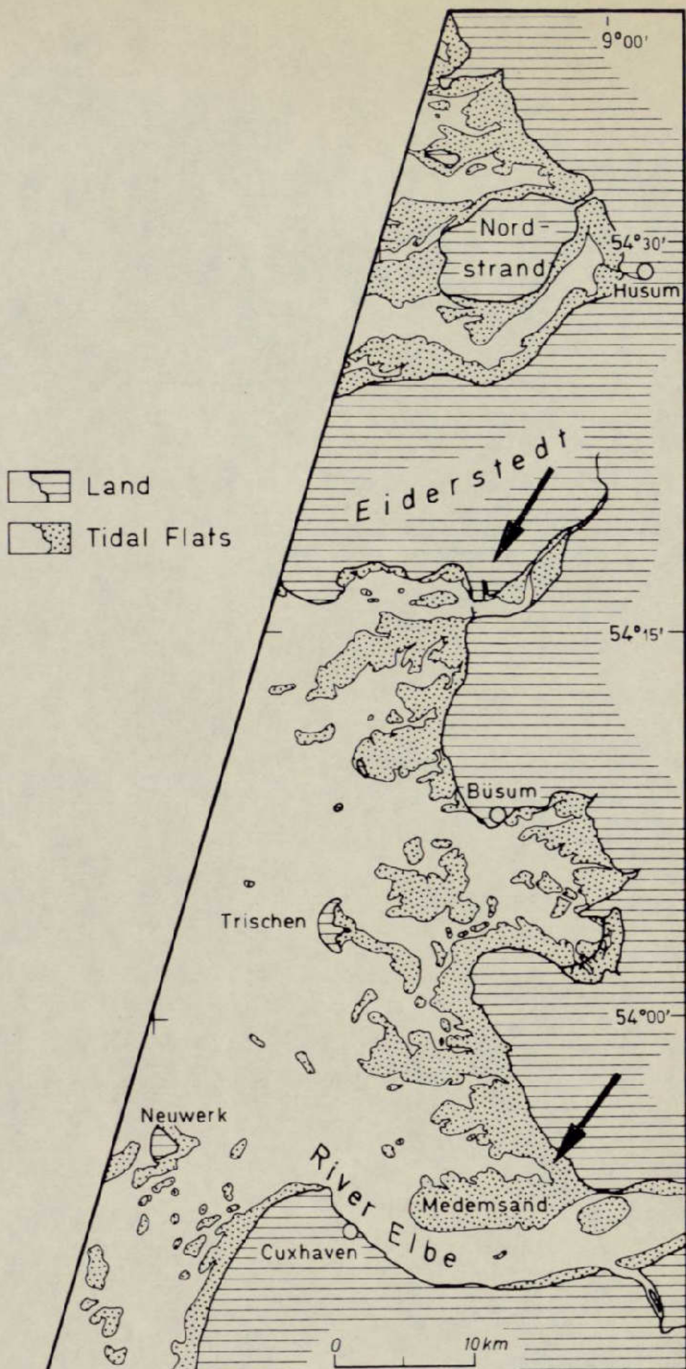
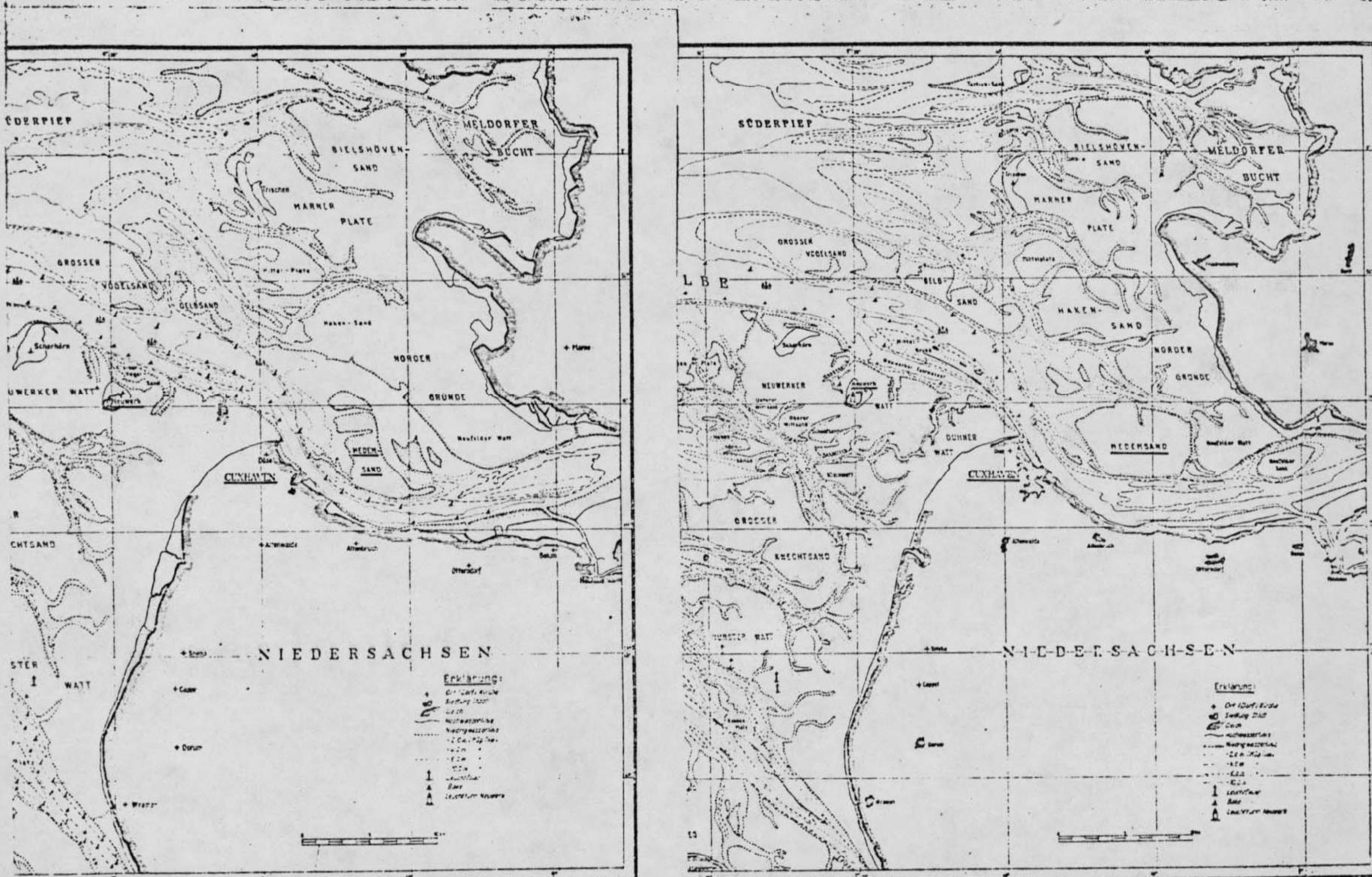


Fig.11

Sketch map of tidal region of German Bight, drafted after ERTS-1 image 1078 - 09532, MSS channel 7, appr. 1,5 - 2 hours after low water on 9. October 1974.

2.2-6b



HOPPE, Fig. 13

Pattern of the tidal flat border and the water depth levels in the Elbe Estuary in the years 1910 (left side) and 1960 (right side). Published by A. W. LANG, 1970.

2.2.1.4. Conclusions

Due to the brief operating times of ERTS over Germany and the large amount of cloud cover included in the few images delivered, the originally planned research programme for the North German coast could not be carried out.

Despite these limitations the experiments carrying out the evaluation of tidal flat morphology for at least parts of the area, have proved the great value of Satellite imagery for detailed improvements to the existing charts. These four Satellite images provide the first complete cover since 1958 of the area under investigation.

In accordance with past custom only main shipping routes are frequently surveyed and as a result sea charts are corrected at intervals of one to two years. This results in an accuracy difference between the main shipping routes and the rest of the map area, despite the fact that these areas are of great importance to the fishing industry and coastal shipping. It is here that the greater photograph coverage that only satellites can provide will remedy the situation. Apart from this, series of satellite image scenes enable the areas with greater change potential to be detected. Where new surveys have to be carried out, the areas concerned can then be exactly described.

The multi-spectral process of ERTS imagery permits the creation of staged relief models, showing shallow water morphology, due to the sharp land water contrast in MSS channel 7 and the different water penetration in MSS channels 4 and 5 (4 - 5 m and 2 - 3 m). For cartographic evaluation the water level differences would have to be computer eliminated.

Bibliography

GIERLOFF-EMDEN, H. G.: Luftbild und Küstengeographie am Beispiel der deutschen Nordseeküste. - Landeskundliche Luftbildauswertung im mitteldeutschen Raum, no. 4, 118 pp., 22 + 49 figs., 13 transp., 1 map, Bad Godesberg 1961

GÖHREN, H.: Studien zur morphologischen Entwicklung des Elbmündungsgebietes. - Hamburger Küstenforschung, no. 14, 71 pp., 57 fig., 1 tab., 1 map, Hamburg 1970

LANG, A.W.: Untersuchungen zur morphologischen Entwicklung des südlichen Elbe-Ästuars von 1560 bis 1960. - Hamburger Küstenforschung, no. 12, 195 pp., 43 pl., Hamburg 1970

KLEMAS, V., BORCHARDT, J.F. & TREASURE, W.M.: Suspended Sediment Observations from ERTS-1. - Remote Sensing of Environment, vol. 2, no. 4, p. 205 - 221, 11 fig., New York 1973

RÜPKE, N.: Neue Erfahrungen mit der photogrammetrischen Vermessung von Watten. - Bildmessung und Luftbildwesen, vol. 34, no. 3, p. 103 - 109, 12 fig., Karlsruhe 1966

SINDERN, F. & KATHAGE, F.: Das Wasserlinienverfahren (Serien-Einzelbildmessung) - eine neue Art der Wattvermessung. - Deutsche Gewässerkundliche Mitteilungen, vol. 10, no. 6, p. 182 - 189, 6 fig., Koblenz 1966

Gezeitentafeln (Tide timetables) 1972, vol. I, Europäische Gewässer. Deutsches Hydrographes Institut Hamburg, Hamburg 1971

Hoch- und Niedrigwasserzeiten (Tide timetable) für die Deutsche Bucht und deren Flußgebiete, 1972. - Deutsches Hydrographisches Institut Hamburg, Hamburg 1971

Maps

Seekarte (Sea Chart) Nr. 49, Nordsee, Deutsche Küste, Mündungen der Jade, Weder und Elbe. Scale 1 : 100 000, 4th ed., Deutsches Hydrographisches Institut, Hamburg 1972 (small corrections 1974)

Seekarte Nr. 50, Nordsee, Deutsche Bucht. Scale 1 : 300 000, 4th ed., Deutsches Hydrographisches Institut, Hamburg 1967 (small corrections 1969)

Seekarte Nr. 107, Nordsee, Deutsche Küste, Nordfriesische Inseln, Vortrapptief, Norder- und Süderaue. Scale 1 : 50 000, 2nd ed., Deutsches Hydrographisches Institut, Hamburg 1967 (small corr. 1970)

Seekarte Nr. 108, Nordsee, Deutsche und Dänische Küste, Lister Tief. Scale 1 : 50 000, 3rd ed., Deutsches Hydrographisches Institut, Hamburg 1968 (small corr. 1970)

Luftbildplan (air photo mosaic) des schleswig-holsteinischen Wattenmeeres. Befliegung 1958 (N. RÜPKE), scale appr. 1 : 251.700. Bildarchiv Landesamt für Wasserhaushalt und Küsten Schleswig-Holstein.
Publ. in: KÖNIG, D.: Deutung von Luftbildern des schleswig-holsteinischen Wattenmeeres, Beispiele und Probleme. - Die Küste, no. 22, p. 29 - 74, 76 fig., Heide i. Holst. 1972

2.3. Geodesy - Cartography

The updating of existing maps is necessary due to the rapid changes in urban areas and in the traffic networks. It is impossible for the map producing organizations to evaluate all the planning data to update their maps. Aircraft flights are therefore the normal tool used to generate thematic maps. However, for small scale maps which only show a limited number of units, air photos contain too much information, most of it irrelevant for the map to be updated. Orbital photography however, shows in most cases exactly the detail which is necessary to produce small scale maps.

(NASA SP-230 1970: Ecological Surveys from Space; USG, 1970; Apollo 6 Photomaps). The following two articles describe attempts to use ERTS-1 images for photo-map production.

2.3.1. Application of ERTS-1 images for the production of multiscale photomaps by H. KNORR and H. FÖRSTNER - Institute for Applied Geodesy - Frankfurt

2.3.1.1. Preface

The aim of the research programme performed by the "Institut für Angewandte Geodäsie" within the scope of the multidisciplinary geoscientific project of the NASA is to investigate whether and to what extent the data obtained by ERTS-1 can be used for small-scale mapping (preparation and revision of map series), in particular for the 1 : 1 000 000, 1 : 500 000 scales and - if possible - also for the 1 : 200 000 scale. As a basis of valuation serve the mapping specifications or regulations on the preparation of the different map series. The programme of the Institute within the ERTS project comprises four subjects:

- Investigations on the topographic information contained in the ERTS image data.
- Investigations on the usability of ERTS image data for the preparation of photomaps at 1 : 200 000, 1 : 500 000, and 1 : 1 000 000 scales.
- Investigations on the geometric information contained in the ERTS image data.
- Investigations on the thematic information contained in the ERTS image data with respect to land utilization, regional planning, environmental protection, etc.

2.3.1.2. Investigation Equipment and Investigated Material

2.3.1.2.1. Equipment

For the evaluation of the paper prints and diapositives, a Zeiss Zoom-Stereomicroscope III (magnification: from 16 x to 100 x), a Zeiss Mirror Stereoscope, and a Zeiss Stereotope have been used.

Tests to produce colour products have been performed at the "Bundesforschungsanstalt für Raumordnung und Landesplanung" at Bad Bodesberg, by means of a SDC-Viewer Model 62 and at the "Siedlungsverband Ruhrkohlenbezirk" at Essen, by means of a I^2S Mini-Addcol-Viewer Model 6000.

For investigations as to the geometry of the image data, a Zeiss Precision Stereocomparator PSK 1, and a Coordinatograph connected to the Stereoplanigraph C8 have been used.

For photomap preparation, the ERTS-1 image data have been adapted to the anticipated map projection by means of a Zeiss Precision Rectifier (SEG V).

2.3.1.2.2. Photographic Material

The working material supplied by the NASA consists of paper prints, transparencies (9 inch x 9 inch), and 70 mm film transparencies in the four spectral bands prepared from images covering the Federal Republic of Germany and the neighbouring countries. Furthermore, investigations of magnetic tape data of a North German scene (1060 - 09534) have commenced. A playback of this scene at 1 : 200.000 scale by means of the KPU plotter has been placed at our disposal by the makers Messrs. Prakla-Seismos GmbH, Hannover.

2.3.1.3. Investigations on the Topographic Information Contained in the ERTS-1 Image Data

2.3.1.3.1. The Topographic Information of Spectral Band 7

An essential characteristic of the images of this band is the clear representation of hydrography and settlements. Without a great differentiation between sea, inland lake, and rivers, waters appear in black. In particular, waters with a surface larger than the resolution of the scanner (approx. 80 x 80 m^2) are clearly imaged. Due to their line-like appearance even waters of smaller size (small rivers) can partially be recognised if they are situated in the image in a lighter surrounding. In this case, however, they are not in a deep black,

but in a gray shade, i.e. in the smallest representable area element. The intensity of the gray shade is a function of the surface of the object. In the images covering the Federal Republic of Germany all larger rivers (Rhein, Donau, Main, Elbe, Mosel, Isar, Lech, Inn, and others) are identifiable as waters. In the images of band 7, the course of smaller rivers can be followed, their valleys being imaged in this band as depth lines of the relief. This applies, however, only to areas having upland character (e.g. Lahn, Nahe, Altmühl). The differentiation of the relief is part of the information supplied by the images of the near infrared which also includes the images of band 6. Because of the great flight altitude of the satellite, stereo models do not furnish any height values but it is possible to obtain additional topographic information by means of stereoscopic viewing. However, only a few areas have been imaged with a stereoscopic overlap. In order to complete hydrography, the method of stereoscopic viewing has partially been applied to the image "Frankfurt" (21 Sept 1972) by making use of the images of the neighbouring strips "Mosel" (4 Sept 1972), and "Würzburg" (20 Sept 1972). The images of the Alpine region are especially well suited for stereoscopic viewing and evaluation. Stereo models with an overlap of approx. 40 % have been made of the images "Garda-See" (1021-09383 and 1093-09390) and "Mailand" (1076-09442). Although the stereoscopic viewing of satellite images is in many cases hampered by different cloud cover and, in particular, by the different lengths of the shadows (images were taken on different days), it is recommendable for a better identification of the topographic phenomena.

When evaluating the images of band 7 (Frankfurt: 21 Sept 1972), localities with densely built-up areas and with more than approximately 10.000 inhabitants are identifiable, these settlements appearing in a dark grey. In some cases, differences in the building density could also be recognized. While the centres of towns (e.g. Frankfurt, Wiesbaden) appear dark, sparsely built areas appear in a lighter tone. Green zones located within towns (Frankfurt, Köln) appear in a still lighter tone. In addition to hydrography, relief, and settlements, the distribution of pine-wood is to a large extent also identifiable in the images of band 7 due to it dark tone.

The identification of roads varies considerably. With the aid of the images of band 5, some images (e.g. "München": 13 Aug 1972 and 6 Oct 1972) allow for a relatively precise drafting of the dual highway net. Partially, even the type of intersections (e.g. clover leaves) is identifiable. Investigations of magnetic tape data and of a direct magnetic tape playback revealed that the information is originally available, but that it is lost when transforming the data into analoguous images. Thus, these analoguous images only reflect a part of the original grey values.

Enclosures to 2.3.1.3.1.:

Fig. 1: Part of ERTS-1 image 1043-10001-7 taken on 4 Sept 1972 over the Mosel river. Blow up of original scene to a scale of 1 : 500 000

Fig. 2: Drainage system of the region shown in Fig. 1 taken from the International Map of the World

Fig. 3: ERTS-1 image 1075-09375-5 showing the cities of Munich and Augsburg enlarged to scale 1 : 200 000

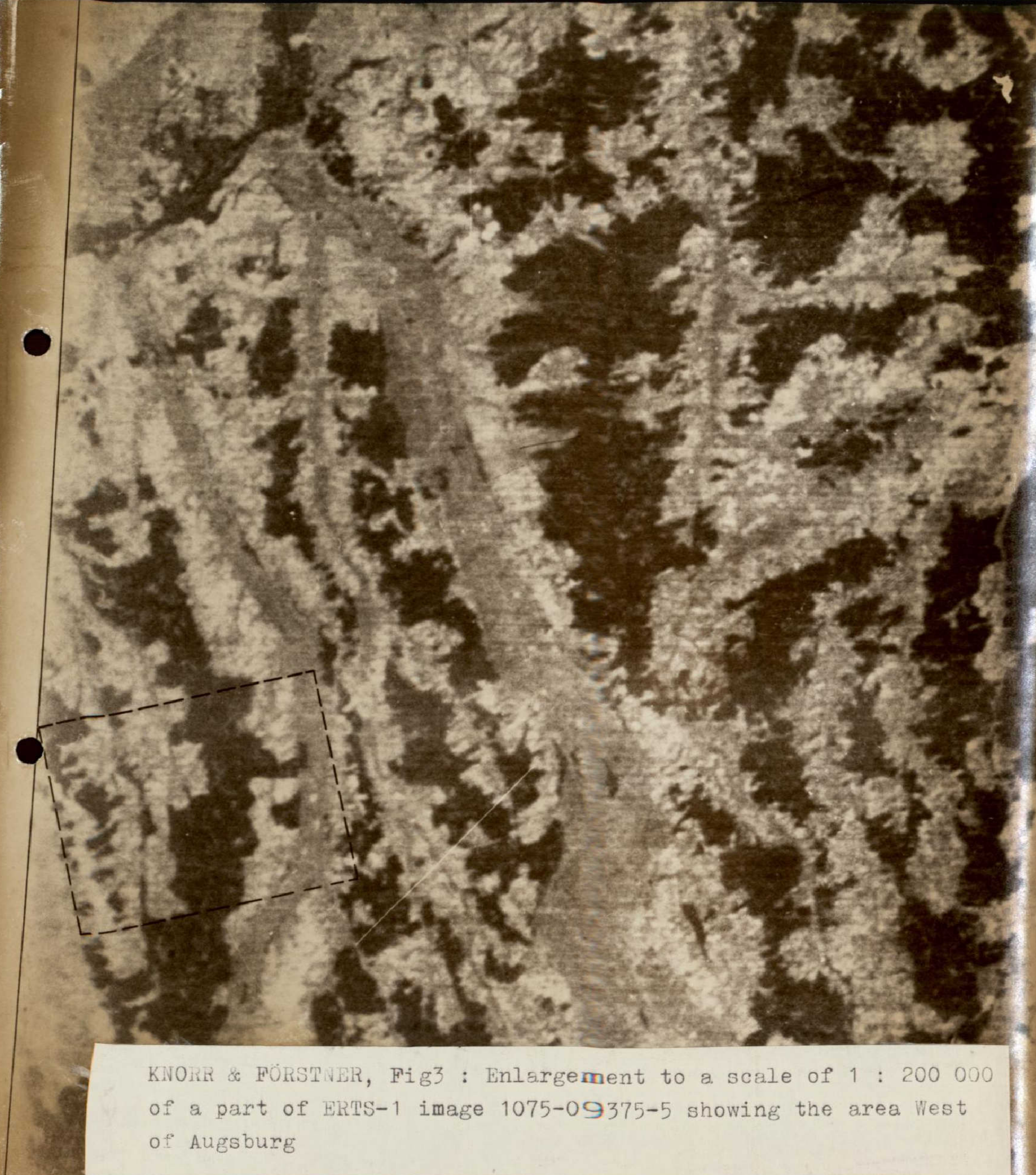
Fig. 4: Band 7 display of Fig. 3 (ERTS-1 image 1075-09375-7)

Fig. 5: Part of the General Topographic Map 1 : 200 000 West of Augsburg (Bavaria)

Fig. 6: Part of the Topographic Map 1 : 25 000 showing an area West of Augsburg

2.3.1.3.2. The Topographic Information of Spectral Band 5

For cartographic purposes, the images of band 5 show best the different types of vegetation. The entire wooded area i. e. pine wood, mixed wood, and deciduous wood clearly contrast with meadow, boggy area, and arable land. Depending on its use, the arable land shows different shades of grey. But only in connection with the images of band 7 is it clearly identifiable by its geometric structure. Compared to forests, moors and meadows are imaged lighter and in a more constant grey (see enlargement to 1 : 200 000 of the image "München" and map sections shown in Figures 3 and 5).

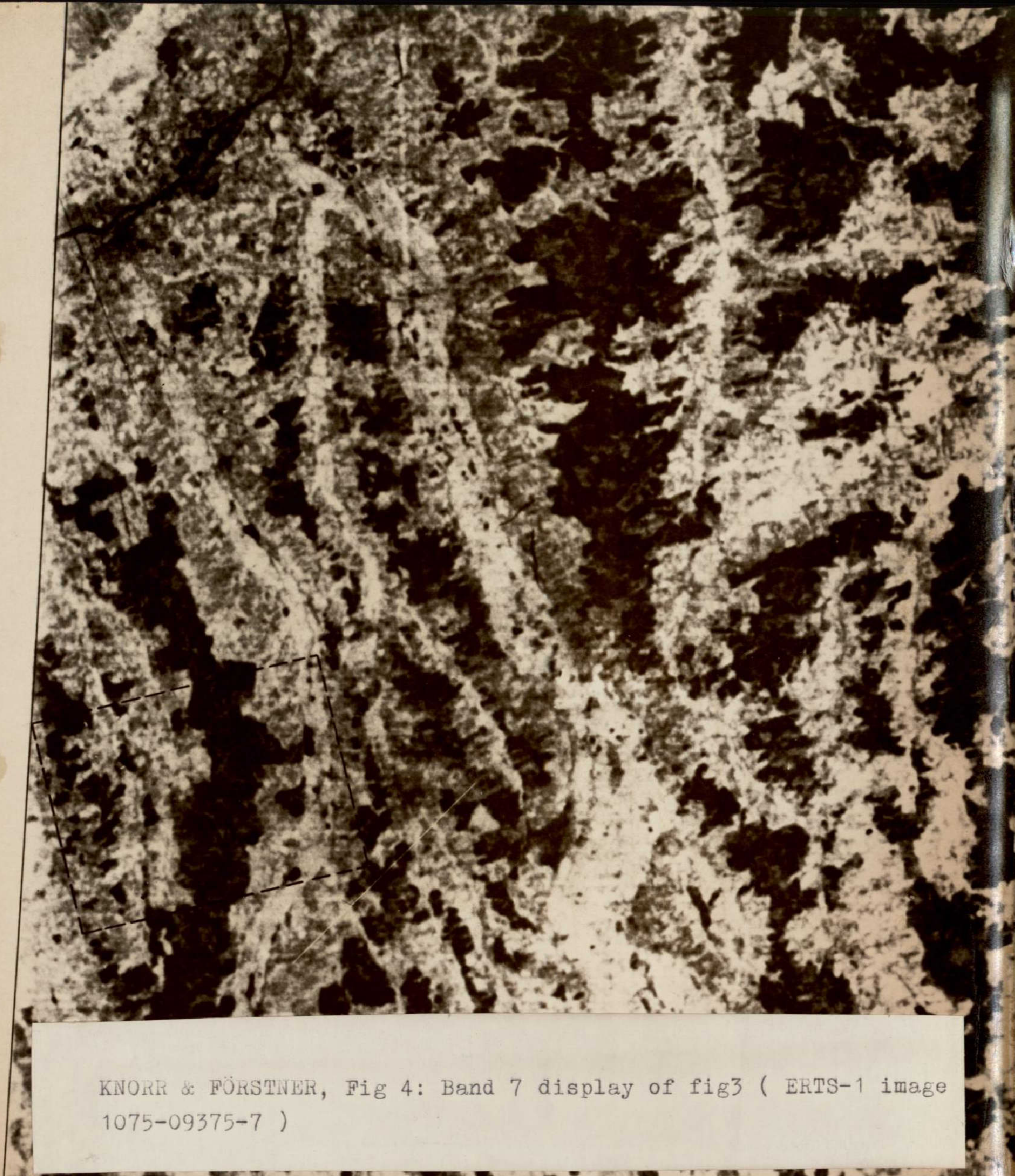


KNORR & FÖRSTNER, Fig3 : Enlargement to a scale of 1 : 200 000 of a part of ERTS-1 image 1075-09375-5 showing the area West of Augsburg

TK 1:25000
7727 Buch

Topograph. Übersichtskarte 1:200000 CC 79

2-3-5-a



KNORR & FÖRSTNER, Fig 4: Band 7 display of fig3 (ERTS-1 image 1075-09375-7)

TK 1:25000
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Topograph. Übersichtskarte 1:200000 C

2-3-5a

LE010-3

Within the dark grey forests, roads appear as light lines (e.g. surrounding of the Rhein-Main-Airport). The attached mounting (Fig. 7) of bands 5 and 7 of the image "München" (6 Oct 1972 ID 1075-09375) practically results in a forest mask of the imaged area. In the South of the Donau river, pine woods prevail, appearing on the image in a dark black. The deciduous woods located in the North of the Donau are shown in a dark grey, being only weakly imaged in band 7.

2.3.1.3.3. The Topographic Information of Colour Composite Products

Within the scope of our research programme, colour composites have been prepared from bands 5 (blue), 6 (green), and 7 (red). These colours and bands have been selected to achieve a better graphic evaluation. The tone of the produced colour composites could be matched well, if the black and white diapositives prepared of the respective bands of different images has the same density.

The examination of the colour composites as to an optimum resolving power and thus to an optimum identification of the topographic content, however, had worse results than the evaluation of the images of the single bands. The reason for this must probably be attributed in the first place to the lack of a direct copying device to be connected to the used colour composition equipment, so that the colour composites had to be photographed from the ground glass. This not only affects the resolution of the images but the geometric accuracy as well. Therefore it is recommendable to use the black and white diapositives of the single bands, if the purely topographic content shall be mapped with great planimetric accuracy. If, however, changes in vegetation are to be represented by areas, only colour composites furnish positive results.

2.3.1.3.4. The Topographic Information of the Direct Magnetic Tape Playbacks

The magnetic tape playback of a North German scene at 1 : 200 000 scale shows a great part of the topography as is required for the preparation of the map 1 : 200 000. Such playbacks frequently furnish - in addition to the information obtained from other prints - information on railroad lines and roads. The agriculturally used area is well differentiated and even smaller rivers contrast well with their surroundings.

2.3.1.3.5. Abstract

If we use as a standard of comparison for the usability of ERTS-1 image data for cartographic purposes the content of the map series for which the images are to be utilized, we find that many important features of topography can be gained from the existing material i.e. analoguous images and magnetic tape data for the 1 : 1000 000, 1 : 500 000 map scales, and - with some restrictions - for the 1 : 200 000 scale. This applies in particular to hydrography and to wooded areas (see image "Mosel" Fig. 1 and drainage plate, forest mask of the image "München" of 6 Oct 1972).

2.3.1.4. Investigation on the Suitability of the ERTS-1 Image Data for the Preparation of Photomaps

2.3.1.4.1. The Preparation of the Space Photomap 1 : 1 000 000

The space photomap attached as Fig. 8 has been prepared by means of positive transparencies adapted to the anticipated map projection in the rectifier. A drainage plate of the International Map of the World, sheet München, served as a basis for the adaptation the images of band 7 serving as model pattern. Due to the difference between the projection of the map and that of the satellite images, the rectification is indispensable.

Due to the fact that so far only a few images of the Federal Republic of Germany are available not all the areas of the map sheet could be represented without clouds. A photomap prepared from the images of one band (band 7) can of course only show what has been imaged in this band (see evaluation of band 7).

In order to disturb the effect of the photomap as little as possible, only some places have been provided with their names although most of the places shown on the International Map of the World are also indentifiable on the photomap.

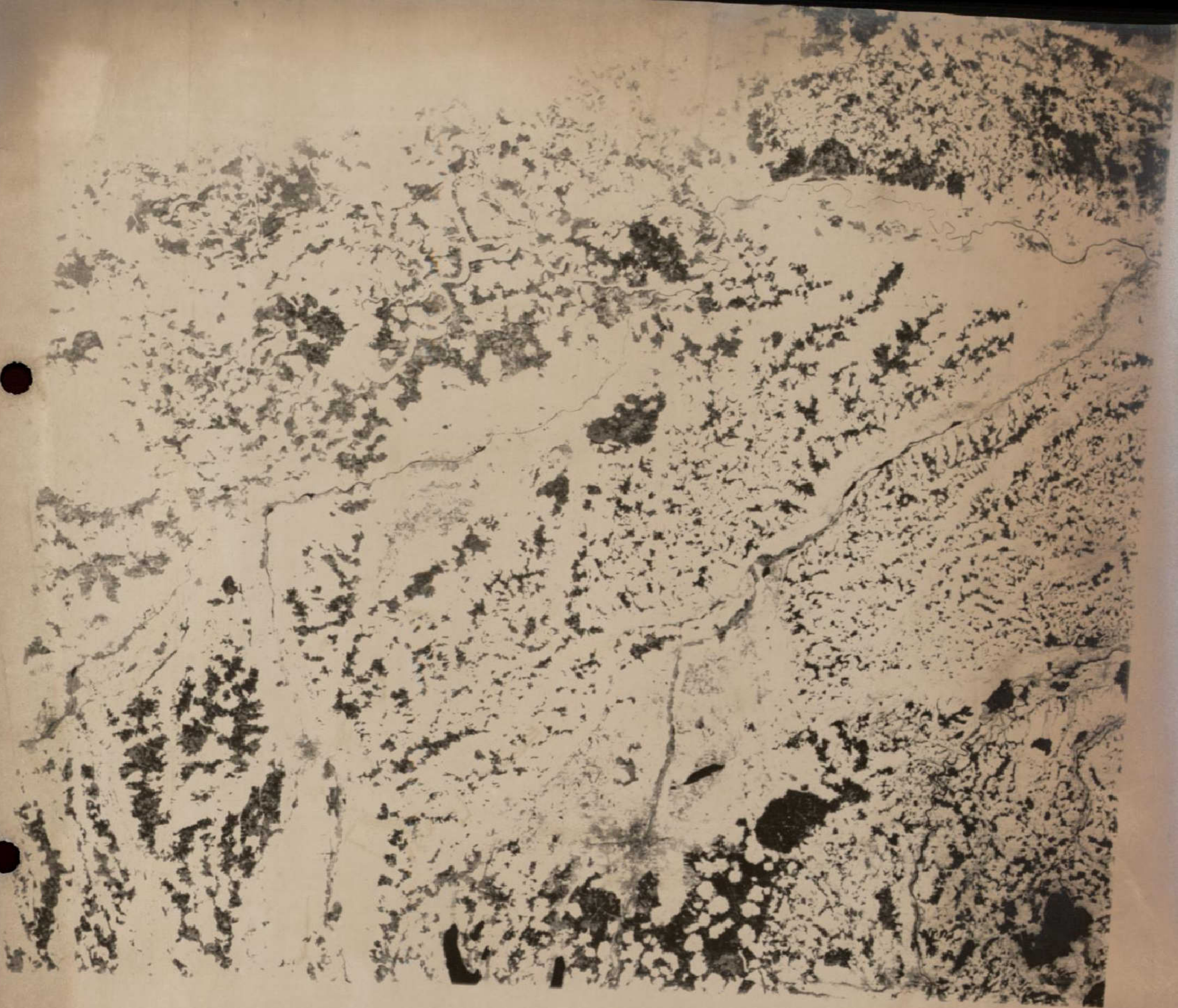
2.3.1.4.2. Preparation of Space Photomaps at 1 : 500 000 and 1 : 200 000 Scales

On principle, space photomaps at 1 : 500 000 and 1 : 200 000 scales (e.g. for the Aeronautical Chart) can be prepared by the same procedure. It must be considered, however, that the planimetric errors increase proportionally.

The preparation of space photomaps at 1 : 200 000 scale (General Topographic Map) by optical enlargement and rectification of the existing imagery is limited to a few areas, as only some images can be enlarged with the required accuracy. Furthermore, several images must be available for the map sheet concerned, the rectification of a single image leading to gaps within the photomap.

2.3.1.5. Investigations on the Geometric Information Contained in the ERTS-1 Image Data

In order to judge the suitability of satellite images for cartographic purposes, it is necessary to identify topographic points with a planimetric accuracy corresponding to the drawing accuracy (approx. 0.1 - 0.2 mm). This means that for the 1 : 1 000 000 scale, a point accuracy of approximately 200 m is required.



KNORR & FÖRSTNER Fig. 7: Composit of bands 5 and 7 of ERTS-1 scene 1075-09375 showing the area of Augsburg and Munich (lower center)

2-3-8a

2.3.1.5.1. Methods of Determining the Planimetric Accuracy of Topographic Points

To determine the planimetric accuracy of the images, reversed contact copies of band 7 positives have been prepared on glass.

The theoretical coordinates of the points to be measured have been taken from the Topographic Map 1 : 25 000 (provided with UTM grid) with an accuracy of 5 m. The coordinates not already located in the 32nd strip, have been converted to this strip.

Characteristic points located near water features (pointedly shaped river mouths, points of islands, distinct curves of rivers, etc.) served as control points in the images. The selected points have been provided with rings. Furthermore, a sketch of the position of each point has been prepared serving as an aid in the evaluation of points in the comparator. All points of an image have in turn been measured. This measurement has been repeated six times in order to exclude uncertainties in the identification of control points. The data obtained have been averaged and transformed to the map coordinates of the UTM grid by a Helmert transformation. Because of its large size, the image at 1 : 200 000 scale (Prakla image, direct tape playback) has been measured in a coordinatograph.

2.3.1.5.2. The Error Distribution in the Images "München", made on 13 August 1972 and on 6 October 1972

Out of these images the coordinates of the same points have each been determined by the above-mentioned method, in order to compare the coordinates of the respective topographic points contained in different images. The points contained in the image made on 13 August 1972 have been measured on prints of 9 x 9 inch size and on 70 mm film while the points contained in the image on 6 October 1972 have only been measured on 70 mm film.

The mean coordinate error of the image of 15 Aug 1972 amounts to 141 m and 150 m, respectively. It shows the good planimetric accuracy of single points on the images prepared by bulk process. It is to be assumed that the maximum error is due to a change in the drainage net, the theoretical coordinates having been taken from a map series approximately 30 years old. These reasons and the uncertainties in the identification of the points have led to different error vectors of closely neighbouring points. With the exception of single deviations, both measurements of the image of 13 Aug 1972 show the same error vectors. The distribution of errors does not show any systematology.

The mean error of the image of 6 Oct 1972 only amounts to 76 m, this being proof of the good geometric quality of the ERTS-1 images. The maximum error amounts to 170 m, i.e. it is below the drawing accuracy corresponding to the image scale of 1 : 3 368 000. The geometric accuracy of this image is partially due to the good photographic quality and partially due to the correction probably being better.

2.3.1.5.3. The Error Distribution in the Magnetic Tape Playback Produced by the KPU Plotter

Upon completion of the Helmert transformation, the error diagram shows a clear systematology as the tape data have been played back on a rectangular coordinate system. Originally, however, the data are not arranged vertically to each other, as during the flight the scanner records data having different Y values at the left and right margin of the image.

The mean coordinate error with this tape playback amounts to 906 m, the maximum error being 2 370 m.

In order to reduce the error, an affine transformation has been performed, thus reducing the mean coordinate error to 81 m and the maximum error to 162 m. The error distribution within the image shows no more systematology.

Although the errors still exceed those permissible within the drawing accuracy for 1 : 200 000 scale (drawing accuracy of 20 - 40 m), this example nevertheless shows that magnetic tape data can be geometrically improved or corrected by relatively simple mathematical methods for a larger scale, too, this all the more, if we take into consideration that larger point errors are to be attributed to uncertainties of identification.

2.3.1.6. Abstract

The investigation of the ERTS-1 imagery (analoguous images and magnetic tape data) has shown that this material is suited for cartographic purposes, in particular for small-scale mapping. The results can be improved by applying evaluation methods which make full use of the entire informational content of the magnetic tapes. These tapes contain a great part of the topographic data such as are required for the preparation of small-scale map series. Although the geometric accuracy is good it can probably still be improved by improving the mathematical models.

2.3.2. Geometric Accuracy of ERTS-MSS Imagery by H.P. BÄHR, Institute of Photogrammetry, Techn. Univ. Hannover

Photogrammetry supplies comprehensive experience of geometric image processing in general. The Institute of Photogrammetry at the Technical University in Hannover works in the field of geometric evaluation of non-conventional photography. Investigations were initiated by Dr. G. KONECNY, director of this institute after a 12-year-stay in North America.

To establish geometric accuracy of ERTS-1-MSS-imagery, a bulk photo taken 21st September, 1972 showing parts of Northern Germany was evaluated. This is one of the rare, relatively cloud-free frames of this region, though cloud patterns in the corners do not allow optimal configuration of ground control points. A film transparency 18 by 18 cm (scale 1 : 1 000 000) of channel 7 (0,8 to 1,1 μm) was measured. As water bodies supply good contrast in the infrared band, all ground control points were without exception selected as landmarks at the borders of water surfaces.

Measurement of image coordinates was carried out with Zeiss Stereocomparator PSK, resulting in ± 10,3 μm rms-error in x-direction and ± 11,4 μm rms error in y-direction. Coordinates of ground control points were read from topographic maps (scale 1 : 50 000) giving ± 6 m relative accuracy.

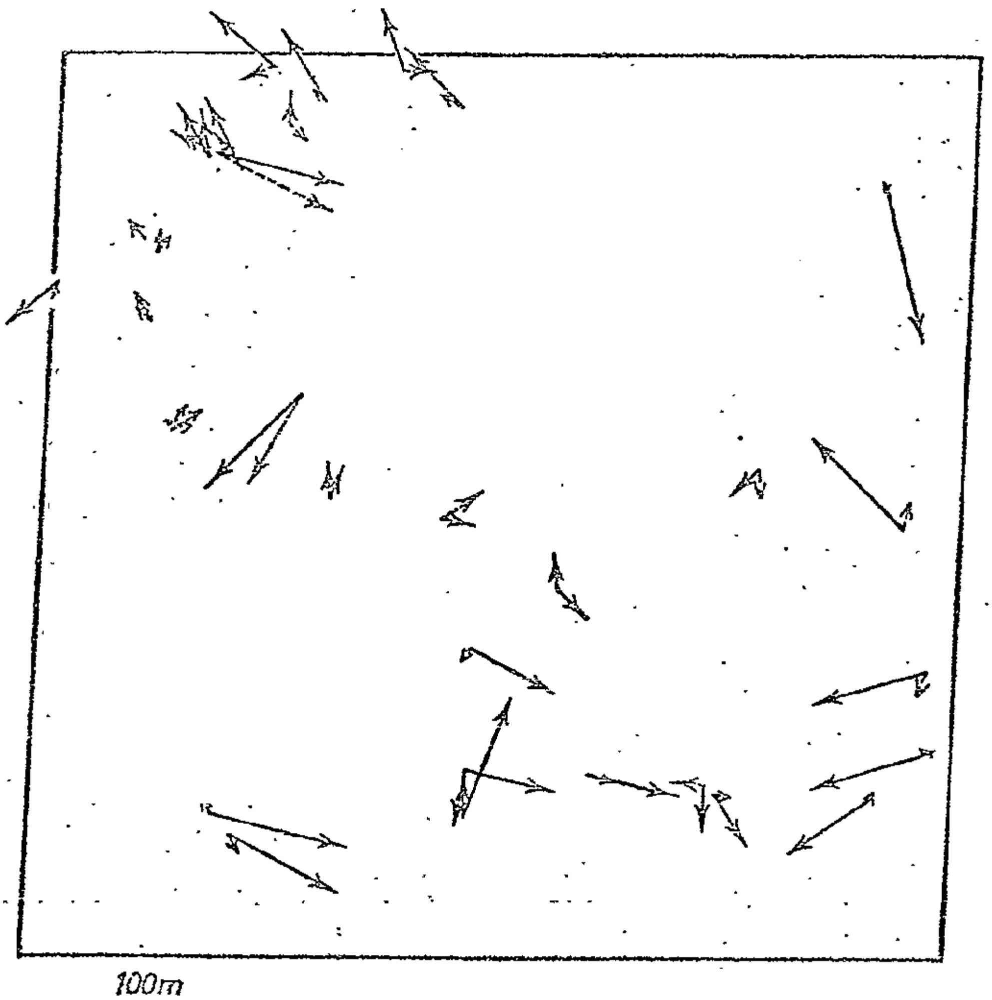
NASA has already corrected ERTS-1 bulk imagery geometrically implying 14 parameters. Since the magnitude of each correction is unknown, there is no way to compute relative orientation parameters, scan rate or other physical parameters from ground control points as we do in conventional photogrammetry. So interpolation by polynomials seems to be the best solution to evaluate geometric accuracy of ERTS-1 bulk imagery.

Coordinates of all 33 ground control points had to be transformed into a uniform system, the 9°-Gauß-Krüger-System (which approximates to UTM-System).

The most simple model adjustment, a 4-parameter-fit

$$x' = x_o + ax - oy$$
$$y' = y_o + ox + ay$$

gives 1 : 996 160 scale and $\pm$ 171 m rms error for transformed coordinates. The vector diagram (solid lines) shows no significant systematic distortions.



Transformation using polynomials of 4^{th} order (30-parameter-fit):

$$x' = a_0 + a_1x + a_2y + a_3xy + a_4x^2 + a_5y^2 + a_6x^2y + a_7x^3 + a_8y^3 + a_9y^2x + a_{10}x^4 + a_{11}y^4 + a_{12}x^2y^2 + a_{13}x^3y + a_{14}y^3x$$

$$y' = b_0 + b_1x + b_2y + b_3xy + b_4x^2 + b_5y^2 + b_6x^2y + b_7x^3 + b_8y^3 + b_9y^2x + b_{10}x^4 + b_{11}y^4 + b_{12}x^2y^2 + b_{13}x^3y + b_{14}y^3x$$

reduced the mean square error of the residuals to $\pm$ 106 m (see small dotted vectors in diagram). A 6-parameter-fit gives $\pm$ 151 m rms error, a 18-parameter fit (second-order-polynomials) $\pm$ 112 m rms error, using 15 ground control points. As a result, we see that errors go slightly down by raising the order of the polynomials, but the effect is small compared to larger computing time. This proves the excellent geometric quality of the image supplied by NASA.

Reference

H.P. BÄHR/W. SCHUHR: Versuche zur Ermittlung der geometrischen Genauigkeit von ERTS-Multispektral-Bildern, Bildmessung und Luftbildwesen, 1/1974

2.4. Geography

Selected ERTS-1 scenes were interpreted by geographers M. BÜRGENER, E. DANIELS, V. KROESCH, and H. SCHAMP from the Bundesforschungs-anstalt für Landeskunde und Raumordnung. G. GLASAUER, prompted by F. FEZER of the Geographical Institute University of Heidelberg, has compiled a critical survey of possible uses for ERTS-1 images.

It could be demonstrated that geographical units represented in the images can be clearly delineated. Parts of the traffic network, rivers, and lakes can be identified. The interaction between urban and industrial areas can be observed. The distribution of microclimatic features can be identified. With repetetive coverage provided it is believed that excellent information on the distribution and mobilisation of dust and air pollution under different weather conditions can be obtained.

Figs. 1 and 2 demonstrate the ERTS-1 capabilities for geographic applications. Fig. 1 is the result of a multispectral survey, using bands 4, 5, and 7 in the colours blue, green, and red. Good results could be obtained for the differentiation between downtown areas, urban areas, and industrial sites.

Fig. 2 gives an example of the identification of geographical units as related to the agriculture-forestry pattern. The patterns are in part also related to sub-surface geology and morphology.

Literature:

GLASAUER, G.: Mitteleuropa im Satellitenbild, Nutzungsperspektiven am Beispiel der ERTS-1-Bilder. - Zulassungsarbeit, Geographisches Institut der Universität Heidelberg, 1973

2.5. Data Processing

During the formulation of the ERTS-A proposal in 1971, data processing from CCT had not reached a stage that could called experimental. The availability of ERTS-1 CCT and the research done in several organisations throughout the FRG, led to the capability of CCT processing and analy sis of digital data. Image enhancements could be used during several investigations. The analysis of digital data led to an automated classification of objects. A raster type plotter for Large scale, high spreed image generation from digital tape was developed.

2.5.1. Digital Evaluation of ERTS-1 CCT

by J. BODECHTEL - Center for Geophotogrammetry and
Remote Sensing, München

2.5.1.1. Abstract

The use of analog and digital image enhancement techniques is studied for different test sites.

In a first step a pure statistical treatment of the data is darried out in order to indicate the high correlation between the ERTS-1 infrared channels.

By the application of different pattern recognition techniques good results could be obtained in separating various surface features. The feasibility of simple density slicinz techniques implemented by an analogue TV-system is illustrated.

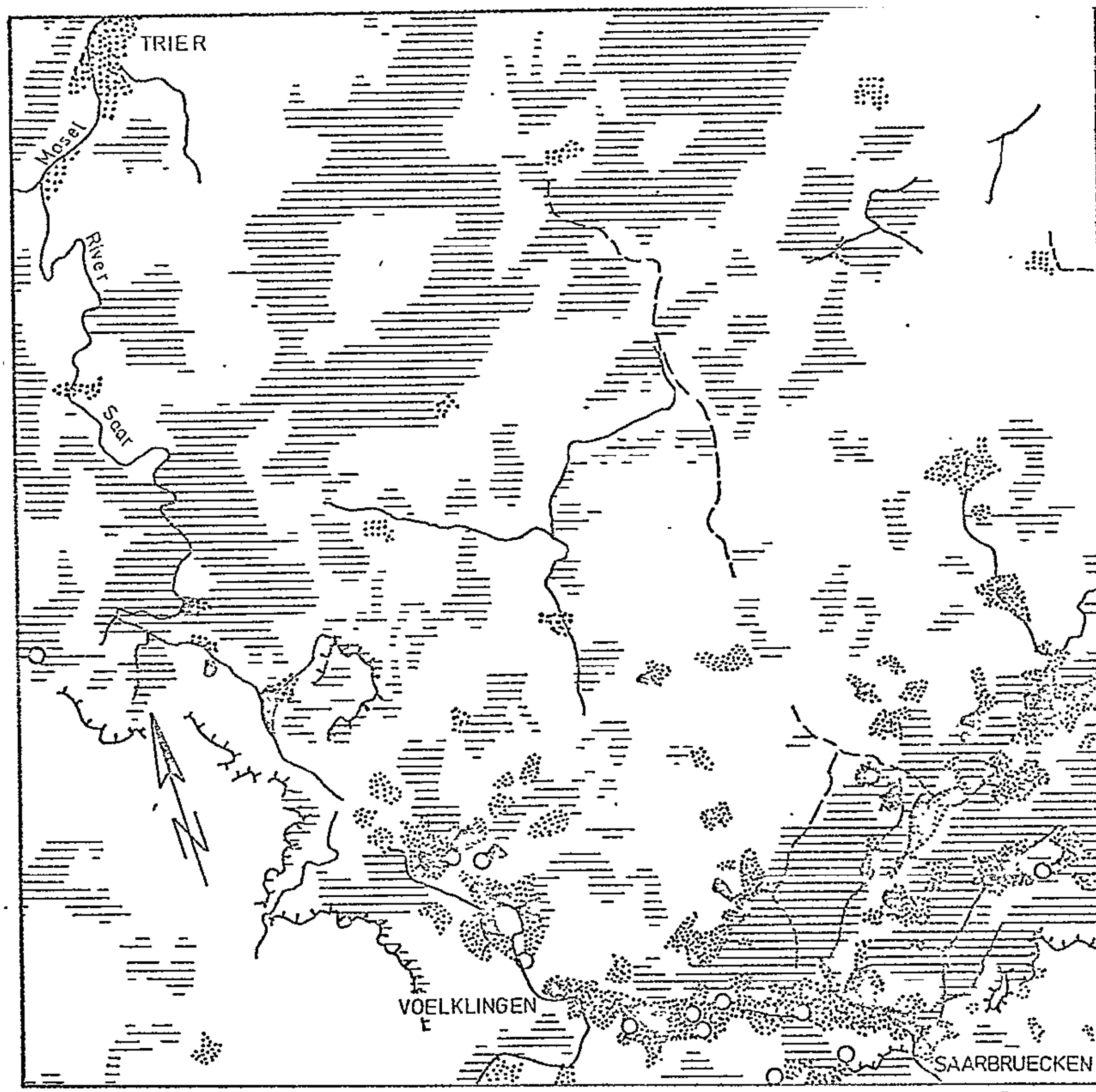


Fig · 1, (Section 2.4)

Legend

Wooded area

Sporsely populated

Densely populated

Industrial sites

Rivers

Roads

Uplift

Saar industrial region.
Part of ERTS-1 image 1043-10001-7.
Analysis made by E.DANIEL and V.KROESCH

2-5-1 a

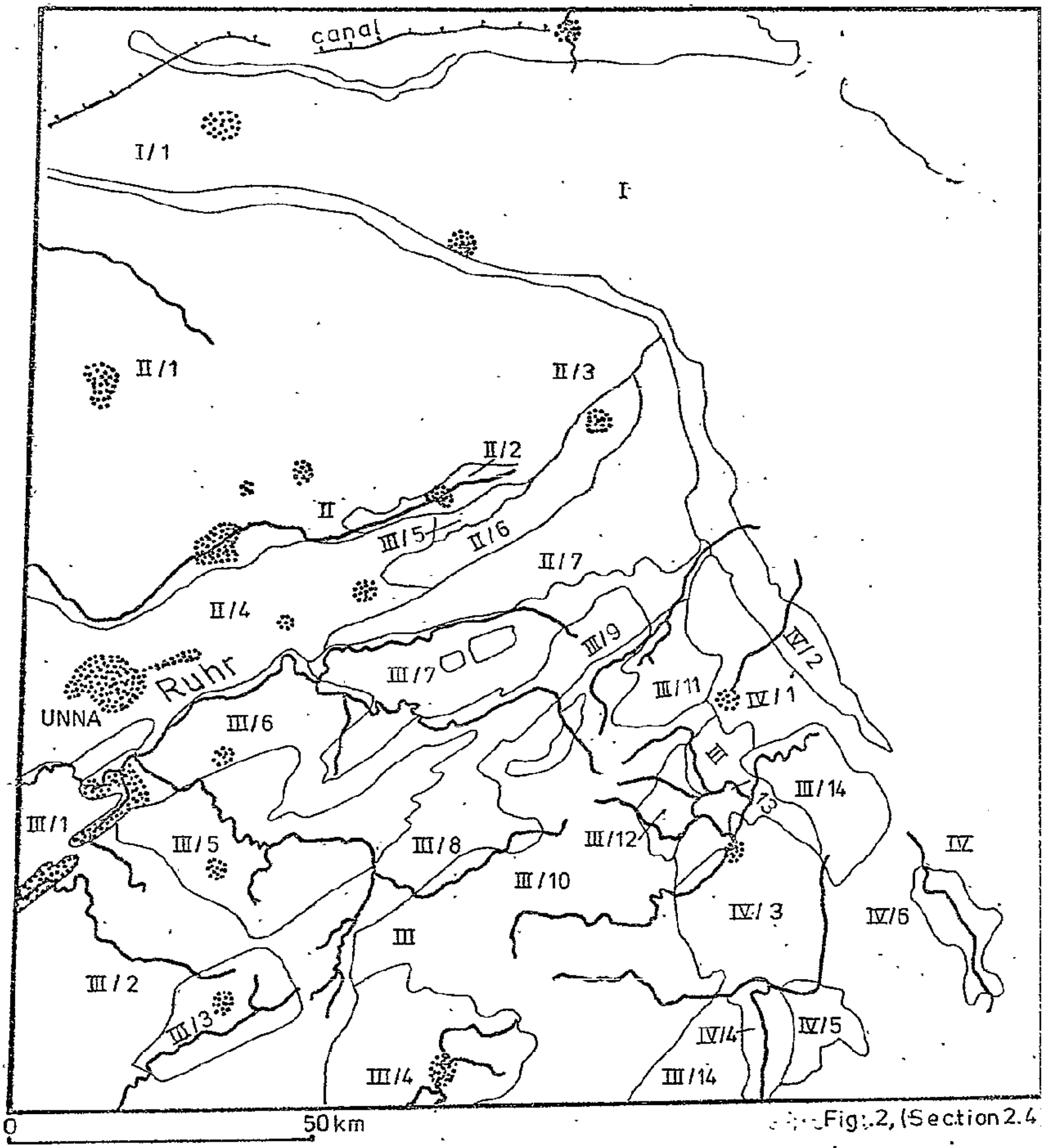


Fig. 2, (Section 2.4

The distribution of land use units and classification as mapped from ERTS-1 image 1060-09540-7 (Westfalia) by M. BUERGENER

I through III/14 = different geographical units
Dotted areas = major towns

2.5-1B

2. 5. 1. 2. Results

An image Analyzer on an optical or electrical basis permits the combination of several spectral bands, which is important in an experimental phase of pre-selection and pre-evaluation of earth scientific phenomena. This leads in a second step to the development of full digitized models. For many earth scientific problems, however analogue techniques remain important and cannot be replaced by digital.techniques.

In this paper an effort is made to analyze ERTS-data by applying digital and analogue techniques.
For most of the European earth scientists, ERTS-CCTapes contain the first available multispectral information in digital form. The lack of experience, in handling this type of data, and the lack of multistage data collection as a necessary basis for systematic investigations on spectral signatures, in the first approach require a software which is necessarily restricted to a more statistical treatment of the data. The development of application and of preprocessing techniques, could not therefore be taken into account.

The main objective of the digital analysis performed was:

a) to check the data quality,

b) to identify picture items by methods of cluster interpretation based on the experience gathered on test areas,

c) to advance an automatic identification and interpretation procedure for the recognition of known and unknown datapoints by means of an evaluation of statistical populations.

Being limited with computer time, the digital evaluation was restricted to a Central European test site south of Munich, for statistical interpretation.

From this region two small representative areas were chosen to obtain a representative cross section of typical terrain classes. The first area is situated at the South end of the Starnberger See in the vicinity of Munich ("Ostersee"-area). This area exhibits water bodies, agricultural, urban and forested areas and also plant soil associations which are characterized by extreme changes in soil moisture. The part of the scene 1059-09475 covering the test site consists of 11760 pixels.

Experimental work in this field aims toward an optimization of these parameters by also taking into account the possible influence of the spectral bandwidths. Therefore in a first step simple statistical investigations on the redundant information represented by the four ERTS bands were carried out.

For this reason, on the basis of the data package of the "Ostersee" area, different channels were compared by plotting the intensities or intensity combinations against each other in the cartesian coordinate system. In this way a distinct linear relationship between the ERTS-Infrared channels (MSS 6 - MSS 7) intensities became evident.

Assuming a straight line as the best correlating curve to the data package, the constants A_1 and A_2 in the linear equation for channel 6 and 7

$$I_6 = A_1 + (A_2 \times I_7)$$

were found to be 5.3059 for A_1 and 1.5101 for A_2 for the Ostersee-Area.

The mean derivation of the measured intensity values and those calculated with the above derived formula as a function of the measured values of channel 7 was found to be 2.2 intensity values out of a scale of 128.

Summerising the results, it can be stated, that a linear relationship exists between channels 6 and 7 for the whole picture for all items. However the linear description derived from a particular scene of landscape cannot necessarily be applied to a different scenery type consisting of two features of unique surface characteristics.

Automatic Classification of Objects

In order to obtain a representative cross section of typical terrain classes, the Ostersee region was chosen to develop and prove criteria for spectral signature identification.

The way to analyse scatter diagrams by comparing the intensities of different channels to each other, shows that it is rather difficult to identify well seperated populations or clusters.

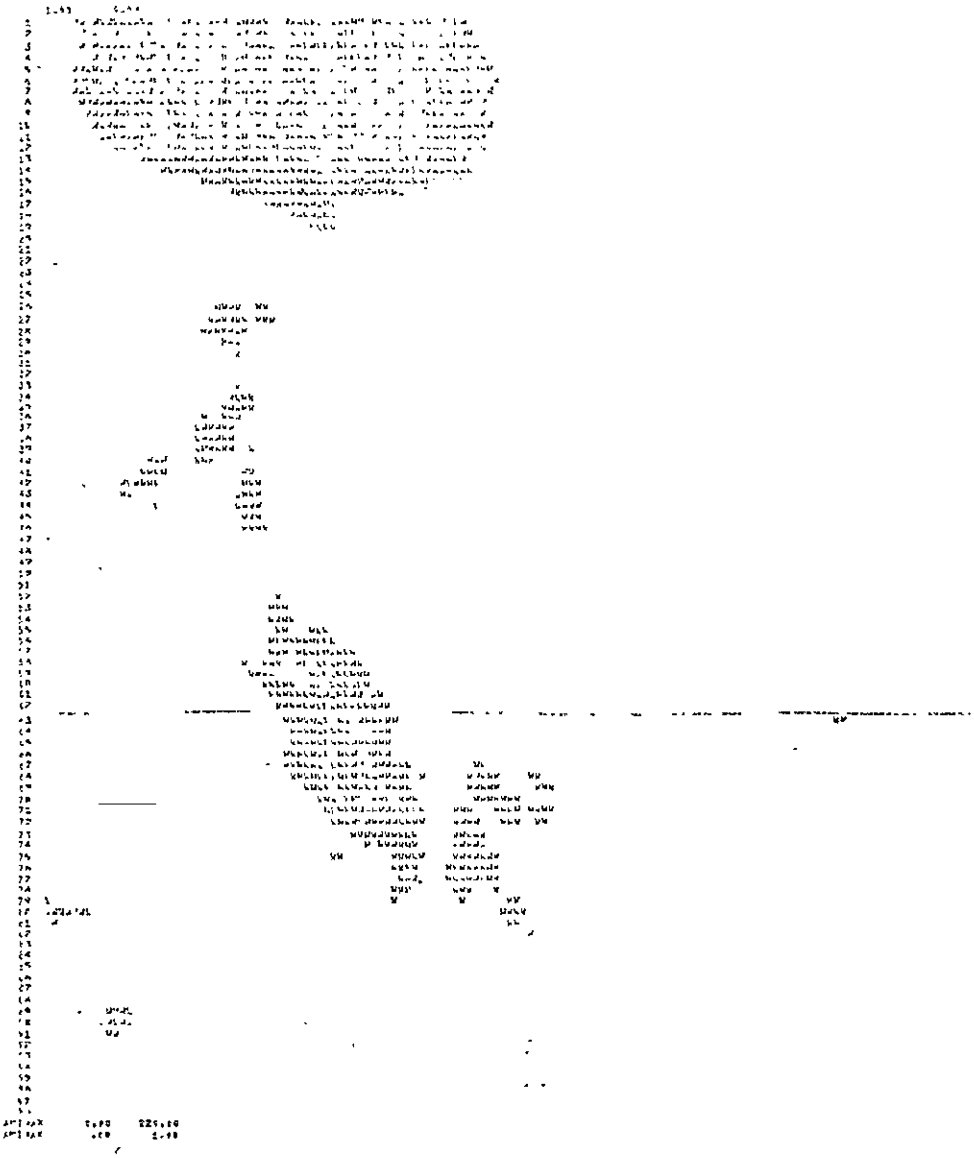
The relatively best result in a two dimensional presentation is a cluster on which the sum of channels (4 + 5) was plotted against the sum of channels 6 and 7. On the basis of this cluster diagram linear decision boundaries seperating the two evident clusters were defined. The output map, which is a non-supervised product of two terrain classes, demonstrated that signature extraction restricted to a two dimensional cluster, does not lead to satisfactory results. The terrain class water could be seperated very clearly fig. 1 but the terrain class representing the second cluster includes forrested areas, areas with various plant soil association and even urban areas.

The high degree of missclassification and the low degree of seperability among a number of categories led to the application of a more sophisticated statistical method, the socalled factor analysis.

By means of the factor analysis it is possible to obtain a statistical classification of the multivariable data, which defines those axes under which maximum seperability of the present categories or populations is given. The result of this analysis shows again the high correlation factor between channel 6 and 7.

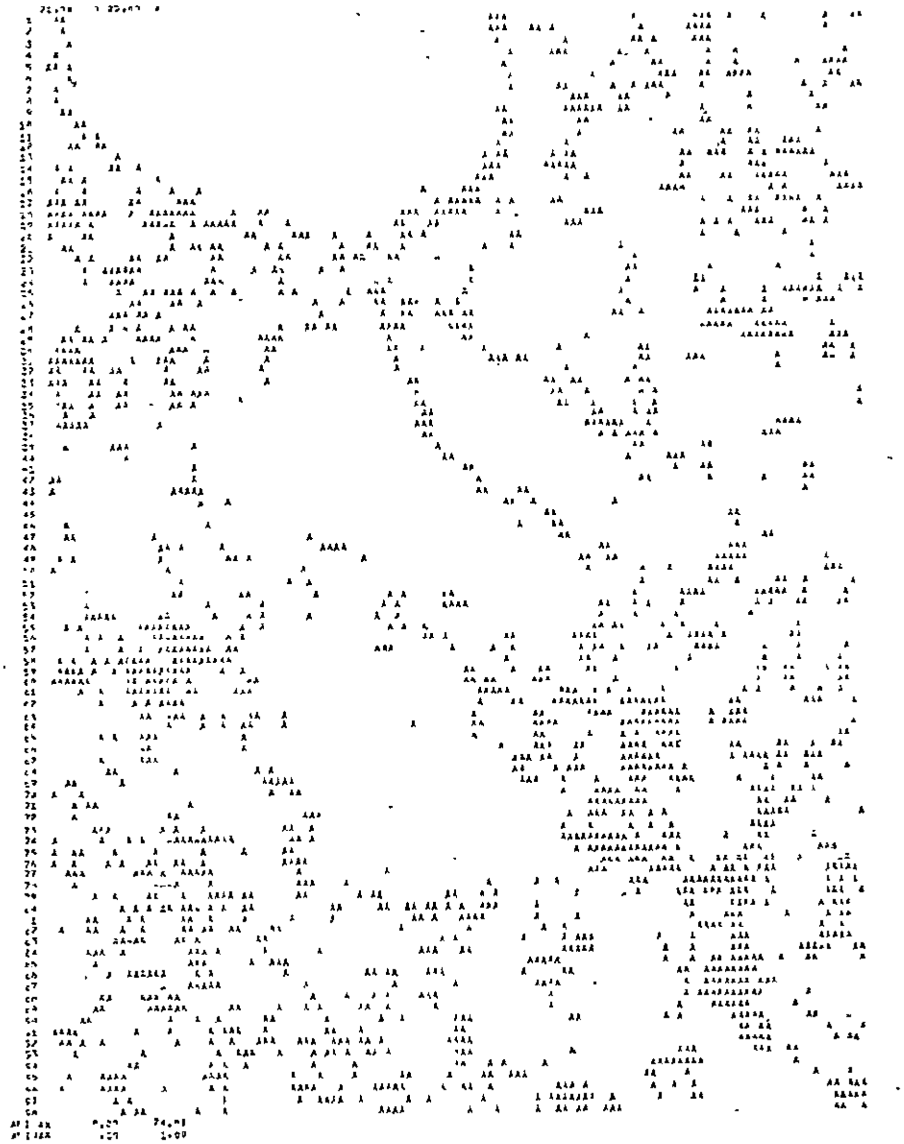
Furthermore it could be derived that from a statistical point of view, 94,2 % of the information which is present in the four ERTS-bands applied can be described by the first two factors. For the further treatment of the data the other two factors describing 5 % and 1 % of the information could be discarded.

On the basis of the newly found factor scores, a more supervised classification technique to the same area could be performed (Fig. 2, 3, 4, 5).



BODECHTEL, Fig. 1 Ostersee area, Bavaria
ERTS-1, 1059 - 09475
computer printout: water surfaces

2-5-5a



BODECHTEL, Fig. 2 Ostersee area, Bavaria

ERTS-1, 1059 - 09475

computer printout: forests and shrubs unclassified

2-5-5-b

ORIGINAL PAGE IS
OF POOR QUALITY

BODECHTEL, Fig. 3 Ostersee area, Bavaria
ERTS-1, 1059 - 09475
computer printout: coniferous forest

2-5-5 c

BODECHTEL, Fig. 4 Ostersee area, Bavaria
ERTS-1, 1059 - 09475
computer printout: agricultural areas

BODECHTEL, Fig. 5 Ostersee area, Bavaria
ERTS-1, 1059 - 09475
computer printout: bare soil

2-5-58

2.5.2. Analysis of ERTS-CCTs

by the Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR), Oberpfaffenhofen

For digital image processing the following equipment is availabe:

Interdata 85-Computer with 24 K und 16 bit-words;
Black and white image-scanner with interface to the computer for READ and WRITE version with a resolution of 10 lines per mm and 8 bit greytone resolution;
Two magnetic Tape Transports (9 track, 800 bpi);

By means of this processing-system the following analysis techniques were applied to ERTS-Digital-Data:

- greytone distribution in all 4 bands
- two dimensional cluster techniques
- display of the last and the last but one significant bit
- display of the difference of two spectral bands
- display of the ratio of two spectral bands
- display of average values
- classification of three image objects: water, cloud and land.

On these studies the following papers were published:

D. KRITIKOS, B. SAHAI and E. TRIENDL
"Mapping of water bodies of Northern Germany from ERTS tapes"
Symposium of European Earth Resources Satellite Experiments, Frascati, Italy, January 28 to February 1, 1974

D. KRITIKOS, E. TRIENDL
"Digitale Verarbeitung und Klassifizierung multispektraler ERTS-Bilder"
Zeitschrift für Bildmessung und Luftbildwesen, 2, 1974.

For these studies CCTs of only three ERTS scenes were available. This is, of course, in sufficient for systematic research. The delay in delivery of ERTS-CCTs was considerable and hampered the progress of work.

Current research intends to evaluate the reflectivity of natural surfaces from ERTS-Digital-Data by means of atmospherical models and ground truth measurements. The aim of this research is the radiometric normalization of ERTS images using the reflectivity. This work is the basis for classification and change detection. Preinvestigation for classification is done by statistical analysis of ERTS images. For this an ERTS image is divided into 256 x 256 picture elements and for every element the following statistical distributions are displayed:

- greytone distribution
- distribution of difference values
- distribution of ratio values.

The purpose of this research is to develop an interactive image analysis system (DIBIAS).

Research staff:

Dr. G. KRITIKOS
Dipl.-Ing. P. NOWAK
Dipl.-Phys. M. SCHROEDEI
Dr. E. TRIENDL

2.5.3. New Raster-type plotter for displaying satellite pictures

by R. SCHULZE-GATTERMANN, Prakla-Seismos GmbH, Hannover

Prakla-Seismos has developed a new raster-type plotter which is able to make playbacks from satellite picture digital tapes. The plotter is a drum type instrument which writes the information on photopaper or film. A cathode ray tube generates small raster points which are close to one another forming the total picture in this way. The grey level of these points can be controlled by varying the light intensity of the cathode ray tube. Completely new is the fact that this plotter is able to make pictures in a large format up to 1 Meter x 1 Meter. It is also possible to generate pictures in any smaller format.

By integrating a minicomputer (PDP 11) in the system the operation of the plotter is in a complete digital form. This gives an exact reproducibility of the display as all parameters for a display are controlled by the software of the plotter system.

The integrated PDP computer is not only able to control the data flow from the magtape to the cathode ray tube but also yields the possibility to make filter operations and any addition or combinations of different channels of the satellite picture. These operations can be made in real-time during the display of the picture.

The time for producing a large format display is minimum ten minutes.

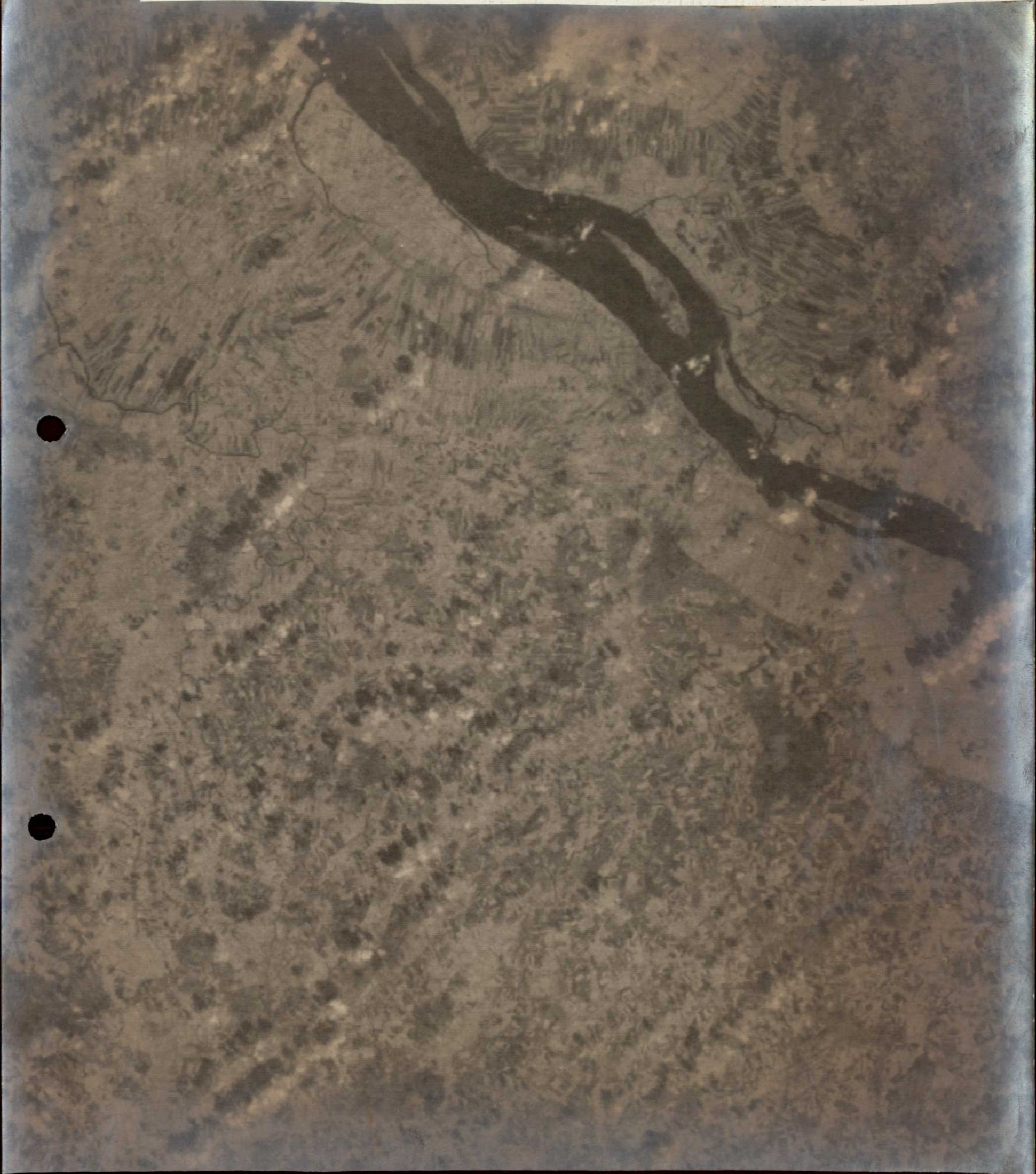
The radiometric resolution is up to 256 steps.

The attached picture (fig. 1) is a part of an original 1 m x 1 m display of an ERTS scene of Northern Germany. It shows the Elbe river from Hamburg to the Estuary. The display was made from channel 7 of ERTS. The geometrical resolution is 0.4 x 0.4 mm. Each of these raster points represents an area of 80 m x 80 m of the satellite record. The radiometric resolution of the display is 64 steps.

2-5-8 a

SCHULZE-GATTERMANN, Fig. 1

Part of ERTS-1 image 1060-09534-7 showing the Elbe river from Hamburg to the estuary. Original display from a new raster-type plotter.



Specifications

Digital drum type rasterplotter with these items:

Data input:	computer compatible 7 or 9-track magtape
Material:	photopaper or - film
Format of display:	maximum 1 meter x 1 meter or any smaller format
Geometrical resolution:	0.4 mm x 0.4 mm or 0.2 mm x 0.2 mm or 0.1 mm x 0.1 mm or 0.05 mm x 0.05 mm
Radiometric resolution:	up to 256 steps
Time for display:	minimum 10 minutes for one 1 m x 1 m display
Data processing:	by the aid of the integrated PDP 11 computer a real-time processing of the satellite data as filtering and/or combination of the channels is possible.